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# THE PHYTOGEOGRAPHY OF MANOA VALLEY, HAWAIIAN ISLANDS

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The present paper represents the first effort, in the long history of botanical exploration in the Hawaiian Archipelago, to make a detailed ecological survey of a representative Hawaiian phytogeographic area. Taxonomic lists and descriptions of new species comprise the bulk of the scientific literature dealing with the Hawaiian flora, and in all of this material there is a conspicuous absence of physiographic and ecologic data. The present paper is based upon field observations extending over a residence of nine years on the island of Oahu, of which time four years have been passed in Manoa Valley itself. The writer has repeatedly visited all portions of this beautiful and historic valley, and has conducted many collegiate field excursions to the numerous points of prime botanic interest.

The writer has availed himself of all accessible records. The nomenclature followed has been chiefly that of Hillebrand's monumental Flora of the Hawaiian Islands (1888). Although this nomenclature is somewhat obsolescent, it is in common usage in the island literature, and it was deemed inadvisable to cumber too greatly these pages with revised names of familiar plants. In numerous instances however, the modern taxonomy has been introduced.

The College of Hawaii is situated in Manoa Valley, near Honolulu. This valley is the immediate natural background of the College and its botanical instruction. Manoa is a representative ecologic area of the Hawaiian mountains. It presents a very clearly defined series of life zones, both in vertical and horizontal planes. It is typical of many valleys in the Hawaiian Islands, and in other parts of the Polynesian Pacific. The phytogeography of Manoa Valley epitomizes that of any similar physiographic region in the archipelago.

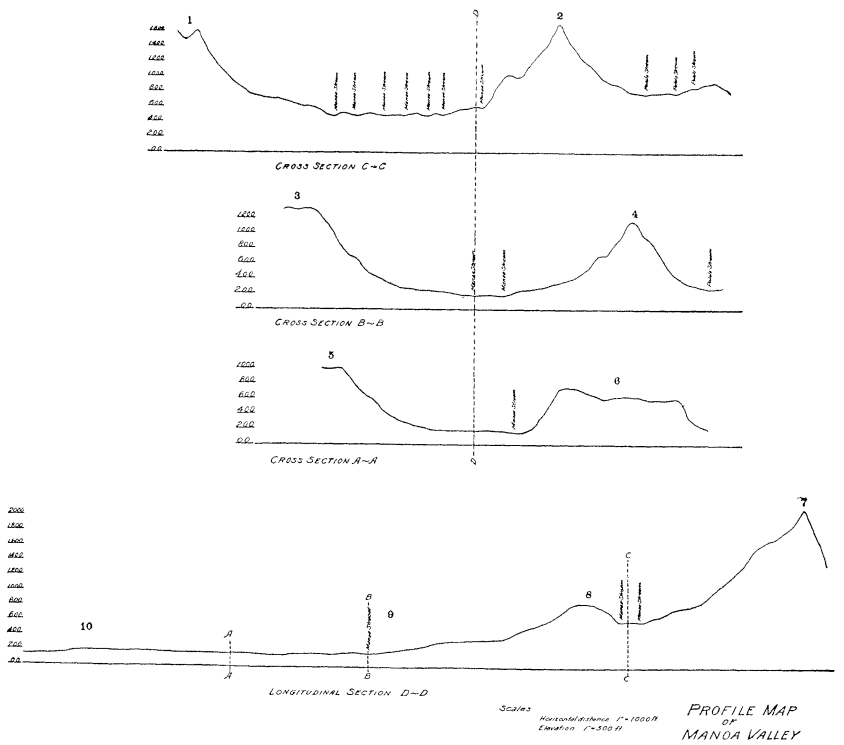



FIG. 1. *Vertical Cross and Longitudinal Sections of Manoa Valley*

1. West lateral ridge; transition region; steep wall into hygrophytic valley-head.

2. East lateral ridge; mountainward portion, covered with rain-forest; eastward slope is into the head of Palolo Valley.

3. West lateral ridge; Mount Tantalus; sloping into middle valley floor.

4. East lateral ridge; apex of foothill.

5. West lateral ridge; Roundtop; sloping into lower valley floor.

6. East lateral ridge; Manoa-Palolo Foothill, about midway between plain and apex.

7. Summit Ridge, near Mount Olympus.

8. Puu Pueo, a median ridge lying along the central axis of the valley.

9. Middle portion of the valley floor, near the point of union of the main tributaries of Manoa Stream.

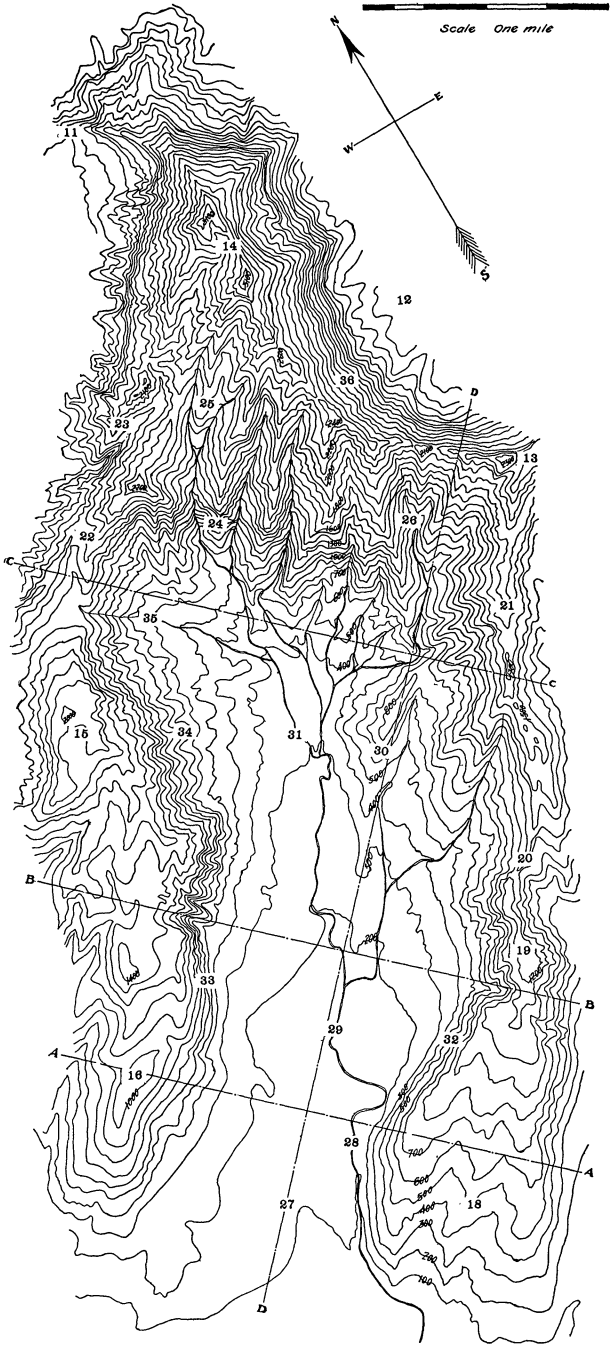
10. The lower valley floor.

Manoa is situated on the island of Oahu, in the vicinity of the city of Honolulu. Residential districts lie along portions of the mouth of the valley and lower western slopes. Much of the floor is occupied by agricultural lands—*taro*, bananas, vegetable gardens, etc. Oahu is third in size among the Hawaiian islands. It is 46 miles long and 25 miles wide, with an area of 598 square miles. It is topographically distinguished from the other islands by being composed of two elongate mountain ranges, Waianae and Koolau. These are of great antiquity, deeply eroded, and give evidence of numerous and extensive elevations and subsidences.

The Waianae Range, lying on a NW.–SE. axis, is about 20 miles long. Its highest peak, Ka-ala, is 4,030 feet high; this is the highest point on the island. The highest point in the archipelago is Mauna Kea, on Hawaii, 13,825 feet. The Koolau Range, in which Manoa is carved, lies to the northeast of the Waianaes, parallel with the latter, at a mean distance of eighteen miles. The Koolau Range is 37 miles long, and is the longest range in the archipelago. It is low, its mean elevation not exceeding 2,000 feet. The highest peak, Kona-hua-nui, rises to 3,105 feet, and lies at the head of Manoa Valley. The range is deeply sculptured by subaerial erosion. There are about fifty major valleys, with numberless ravines and lateral gullies. Manoa is one of the largest of the major valleys.

Manoa is a well-matured valley, with broad flat floor and slightly expanded head. Measured from its mouth or portal (using the 100 feet contour as a base-line), an airline to the crest of the summit ridge is 3.4 miles long. Its width, measured by airline from one lateral ridge-crest across to the opposite ridge-crest, varies from 1.2 miles at the portal to 2.2 miles at the head. Like many other of the larger Hawaiian valleys—Kalihi, Kahana, Iao, Pelekunu, Halawa, Waipio—the head of Manoa is a constantly expanding amphitheater of erosion. The valley widens progressively from portal to head, at the rate of about 5–6 percent.

The Koolau Range lies along a NW.–SE. axis. All the valleys, of which Manoa is one, that deeply furrow its leeward flanks have a dominant southwesterly exposure. The trade winds, which blow almost continuously through a major portion of the year, come from the northeast. The leeward valleys are thus protected from the trade winds by the mountain wall. The maximum of the torrential precipitation that results from the rising of the moisture-laden trades over


Scale One mile
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the mountain rampart falls, not upon the summit crest, but just to the leeward. The heads of the leeward valleys thus receive Oahu's maximum precipitation. The annual average for this is about 150 inches, whereas the precipitation along the crest itself is about 100 inches. Manoa is known locally as a very rainy valley.

Rainfall has been a dominant factor in forming the valley and sculpturing its walls. At present it is the controlling factor in the distribution of the plant life of the valley. The following data, sup-

| Locality | Jan. | Feb. | Mch. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual (Approximate) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Honolulu, on coastal plain, el. 111 ft. | 18 | 3 | 7 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 41 |
| Manoa, middle of valley, el. 300 ft. | 7 | 7 | 8 | 8 | 7 | 6 | 7 | 8 | 8 | 7 | 9 | 9 | 90 |
| Manoa, upper floor, el. 300 ft. | 22 | 3 | 11 | 9 | 28 | 12 | 13 | 19 | 9 | 9 | 17 | 24 | 176 |
| Mount Tantalus, el. 1,360 ft. | 8 | 8 | 9 | 9 | 8 | 8 | 9 | 8 | 9 | 8 | 11 | 11 | 106 |

FIG. 2. *Contour Map of Manoa Valley*

1. Nuuanu Valley Gap; at the head of the valley, cutting completely through the Koolau Range.

12. Ohu-ohi Amphitheater, on the windward side of the Koolau Range.

13. Mount Olympus.

14. Mount Kona-hua-nui, with two summit peaks.

15. Mount Tantalus.

16. Round top Hill; Sugar-Loaf lies directly mountainward, between the former and Tantalus.

18. The Manoa-Palolo foothill.

19. Apex of the Manoa-Palolo foothill.

20. Transition region on the east lateral ridge.

21. Mountainward portion of the east lateral ridge.

22. Topographic transition region on the west lateral ridge.

23. Mountainward portion of the west lateral ridge.

24. Zone of precipices or *palis* that bound the upper valley head.

25. Zone of the hanging valleys; in addition to the five or six large hanging valleys there are numberless small ones.

26. Hanging valleys in the flanks of Mount Olympus.

27. The lower valley floor.

28. Manoa stream, crowded against the foot of the east ridge.

29. The middle portion of the valley floor.

30. Puu Pueo.

31. The upper valley floor.

32, 33, 34, 35. Talus zone and valley walls.

36. Windward wall or precipice of the Koolau range.

plied by the Hawaii Section, U. S. Weather Bureau, shows the rainfall in various parts of the valley, for 1916.

Translating these data into terms of ecologic zones, the approximate annual rainfall is as follows:

| | |
|---|---|
| Coastal plain, seaward of Manoa valley | 41 inches |
| Middle of valley | 90 " |
| Upper valley floor | 176 " |
| Lower forest zone | 106 " |

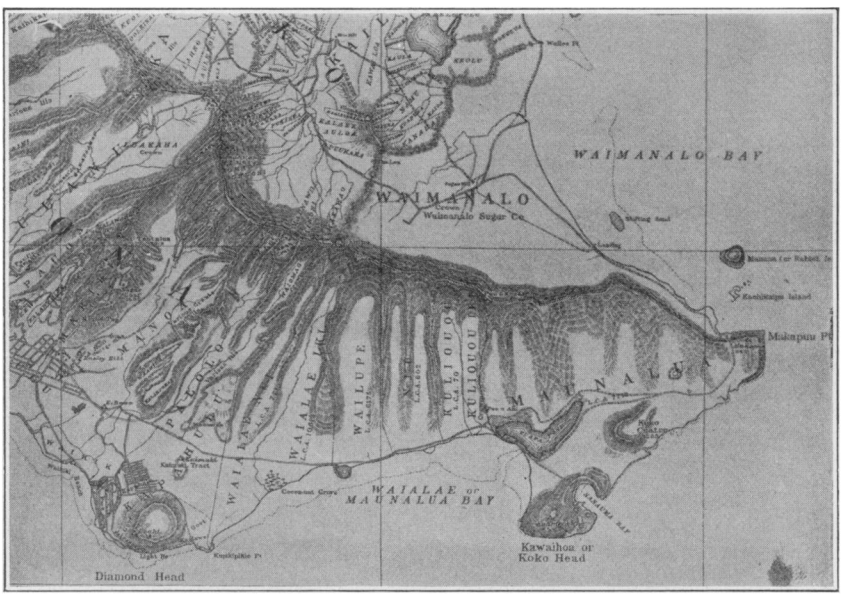


FIG. 3. Map of the eastern end of Oahu showing the relation of Manoa valley to the adjacent land areas.

In general the valley becomes progressively hygrophytic as one advances toward the head, and conversely, progressively xerophytic as one approaches the sea.

In Luakaha, a region in upper Nuuanu Valley, and separated from Manoa by only a narrow ridge, the annual rainfall is about 200 inches (196.99).

The U. S. Hygrographic Survey maintained a rain-gauge on the summit of Mt. Olympus (2,450 feet) for a period of 67 days, and

recorded a daily rainfall of .20 inch. This would be equivalent to an annual precipitation of about 73 inches, a figure somewhat lower than the general average for the rain-forest.

Shreve[1] gives the annual rainfall for three stations in the Jamaica rain-forest as 105.70, 113.85, and 168.02 inches respectively. This corresponds closely with records for the Hawaiian rain-forests, as does his statement that "there is no other form of precipitation than rain, hail and snow being unknown, although the former occurs at

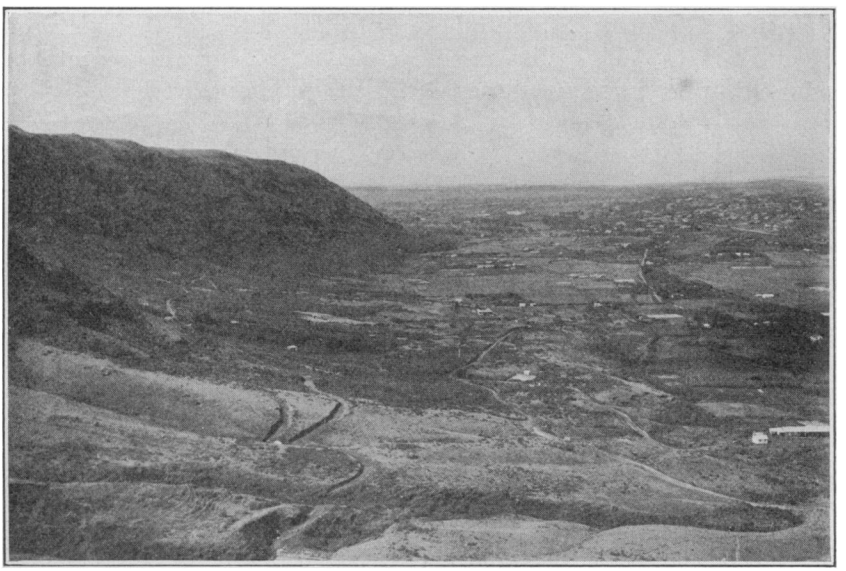

FIG. 4. View of Manoa Valley, from a lateral ridge. Shows plainly the lower floor, talus zone, wall and eastern foot hill.

rare intervals in the lowlands. The frequency of showers too light to register 0.01 inch is high, and they are not without influence on vegetation. Although the number of rainy days is high and the frequency of light showers is high, yet the bulk of the annual rainfall is registered during the prolonged downpours. . . . Dew is formed abundantly in open situations on clear nights at all seasons of the year."

[1] Shreve, Forrest, A Montane Rain-Forest. Carnegie Institution of Washington, 1914.

Although somewhat sheltered from the direct mechanical effects of the trades, Manoa and the other leeward valleys of its class are exposed to the periodical *kona* or southerly storms, which usually occur during the late winter and early spring (January to April). The kona storms are often characterized by heavy winds and excessive rainfall.

The southwesterly exposure of Manoa shuts off its head from a considerable portion of the morning sunlight, and gives prominence to the afternoon heat and light. Manoa is much sunnier and warmer than are the narrow, windy, northerly facing valleys of the windward Koolau slopes. This climatic difference is sufficiently great to be reflected in the respective floras of these two types of valleys.

## 1. THE REPRESENTATION IN MANOA OF THE HAWAIIAN ECOLOGIC ZONES

In the Hawaiian Archipelago there are numerous well-defined ecologic zones. The representation of these life-strata in the Manoa region may be indicated as follows:

1. LITTORAL. *a. Humid littoral;* windward.

   *b. Arid or semi-arid littoral;* leeward. The littoral of that portion of the coastal plain which lies to the seaward of Manoa Valley is of this type.

2. LOWLANDS. Up to 1,000–1,500 feet; with humid and arid sections, depending upon relation of topography to trade winds, and distance from interior mountains. In Manoa Valley the lowland proper (valley floor) lies well below the 500-foot contour; in early times the lower forest zone came down to this level.

3. THE FOREST ZONE. *a. The Lower Forest;* 1,000–2,000 feet; with humid and arid sections. In Manoa this zone lies between 500 and 1,200 feet, and is almost wholly of hygrophytic or semi-hygrophytic character, although some xerophytic forms do occur.

   *b. The Middle Forest;* 1,800–5,000 feet; variable with humid and arid sections on the various islands. In Manoa this zone is typical Oahuan rain-forest; highly hygrophytic, and very rich in endemic forms. Owing to the low elevation of the Oahu mountains, this is the highest zone, and

   *c. The Upper Forest;* 5,000–9,000 feet, is restricted to the high mountains of Maui and Hawaii.

4. THE SUMMIT REGIONS. *a. Xerophytic Summits;* 9,000–14,000 feet; high mountains of Maui and Hawaii.

*b. Hygrophytic Summits;* 4,000–6,000 feet; peaks rising into the cloud zone, Kauai, Waianae, East Molokai, West Maui, Kohala.

## 2. ECOLOGIC ZONES OF MANOA

The main ecologic zones in Manoa Valley are:

1. The Valley Floor:
   - *a.* The Lower Floor (near portal).
   - *b.* The Upper Floor (near head).
2. Manoa Stream and its Tributaries.
3. The Talus Zone.
4. The Valley Walls or Lateral Ridges:
   - *a.* The East or Manoa-Palolo Ridge,
     1. Foothill.
     2. Transition region.
     3. Mountainward region.
   - *b.* The West or Mt. Tantalus Ridge,
     1. Foothill (Roundtop).
     2. Transition region.
     3. Mountainward region.
5. The *Kukui* Zone, Ravines, and Precipices.
6. The Zone of *Koa* and *Lehua*.
7. The Hanging Valleys; Rain Forest.
8. Summit Ridges and Peaks:
   - *a.* Olympus.
   - *b.* Kona-hua-nui.

Topographic, edaphic, climatic, and biotic factors differentiate more or less clearly these zones from one another. On the basis of *water*, the grouping would be, as numbered above:

Hydrophytic...*2*.
Hygrophytic...*1b*, *4a*2 3, *4b*2 3, 5, 6, 7, 8.
Mesophytic.....*1a*, 3.
Xerophytic.....*1a*, 3, *4a*1, *4b*1.

On the basis of *elevation:*

Above 2,000 ft.....*8a* and *b*.
Between 1,000–3,000.....7.
1,000–1,400.....6.
300–1,000.....5.
50–1,000.....*4a*1, *4b*1.
Between 1,200–1,700.....*4a*2, *4b*2.
1,000–2,000.....*4a*3, *4b*3.
100– 300.....3.
50– 300.....1, 2.

On the basis of *mean temperatures:*

| | |
|---|---|
| Notably warm.....1, 4*a*1, 4*b*1. | Cool.....4*a*2, 4*b*2, 5. |
| Warm.....3. | Notably cool.....4*a*3, 4*b*3, 6, 7, 8. |

### 3. THE VALLEY FLOOR

The floor of Manoa is conspicuously broad and flat, much more so than are the floors of the valleys immediately adjacent to it, Makiki, Pauoa, Palolo, and Waialae. This flatness may be considered as one of the evidences of the maturity of this valley.

The designation "floor" comprehends the region lying below the 300-foot contour; roughly an area 2.0 miles by .75 mile. It is composed chiefly of "mountain wash," a heavy, dark reddish-brown, fine-textured, adobe soil, that has been washed down from the surrounding basaltic ridges and spread out as a deep blanket in the valley basin. Along the lower western slopes are extensive deposits of volcanic ash and cinders. The thickness of the soil bedding is not known; along the center of the valley it must be very deep, perhaps hundreds of feet. The red-brown adobe soil is fertile, stiff and intractable in cultivation, and exceedingly retentive of moisture. When it becomes dry to any considerable depth, as during the infrequent droughts, it cracks conspicuously. The cracks are 1 to 4 inches wide and 12 to 40 inches deep.

From an ecologic standpoint the valley floor may be transversely divided into two regions, the floor of the lower valley, *i. e.*, near the portal, and the floor of the upper valley, near the head. The lower floor comprises the area from the portal up to the point at which Manoa Stream diverts from the middle of the valley. The upper floor continues from this latter point to the region beyond the bifurcation of the floor at Puu Pueo. The lower floor is contrasted with the upper floor by greater xerophytism; more brilliant illumination; higher temperatures of air and soil; less surface water in the form of streams, pools, and springs (although more in the form of irrigated *taro* patches); more volcanic material such as surface lava, cinders, ashes, etc.; and smoother contours. The upper floor has a higher percentage of indigenous vegetation, and in former times was wholly covered by the lower forest zone, as will be described in another section.

The valley floor is principally occupied by introduced plants,

including both weeds and economics. The native vegetation is poor in species and quantitatively insignificant. This condition is in striking contrast with that of the rain-forest, only a few miles distant, where the vegetation is almost wholly endemic or indigenous, and where the introduced element is practically negligible.

Some of the larger and dominant plants of the valley floor (aside from those actually under cultivation), are: *Prosopis juliflora*, *Opuntia*

FIG. 5. View of Manoa stream and east valley wall. Looking toward head of valley, which may be seen faintly through the rain. Trees in mid-ground are *Kiawe*, *Prosopsis juliflora*.

*megacantha*, *Leucaena glauca*, *Lantana Camara*, *Psidium Guayava*, *Xanthium strumarium*, *Ricinus communis*, *Indigofera Anil*, *Malvastrum tricuspidatum*, Cassia spp., Sida spp., *Acacia Farnensiana*, Ipomoea spp., *Commelina nudiflora*, Crotalaria spp., *Eugenia Jambolana*, *Stachytarpheta dichotoma*, *Solanum Sodomeum*, etc.

Manoa has been inhabited by the native Hawaiians since very early times. Much of the lower floor was occupied by their tiny plantations or *kuleanas*. The *kalo* or *taro* (*Colocasia antiquorum*

Schott) was the principal crop, and was raised in small irrigated fields or *loi*. The water from these fields was skilfully diverted from Manoa stream by a primitive but highly efficient system of ditches. An area equivalent to several square miles was occupied by the *kalo* fields. Much of this *kalo* land is in cultivation today, although the industry has passed largely into the hands of Orientals.

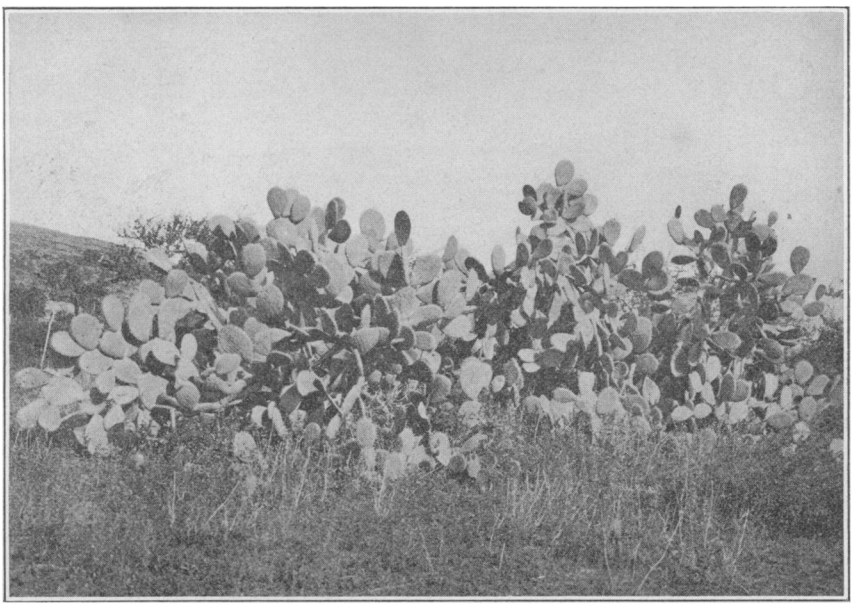

FIG. 6. *Opuntia megacantha*, a dominant xerophyte of the Manoa lower valley floor and foot hills.

Other crops raised by the primitive Hawaiians, and continuing today in small patches here and there, are

| | | |
|---|---|---|
| Sweet potato | *Uala* | *Ipomoea Batatas* |
| Native banana | *Maia* | *Musa sapientum* |
| Sugar cane | *Ko* | *Saccharum officinarum* |

Mention may be made of the eleven avian species that are distinctive of the valley floor and walls. Six of the introduced species are common and of considerable phytogeographic significance, as they are abundant carriers of weed seeds and fruits.

## 4. BIRDS OF THE VALLEY FLOOR

ENDEMIC

Short-eared owl, *Asio accipitrinus Sandwichensis* Bloxam. *Pueo*.....R
Hawaiian coot, *Fulica alai* Peale. *Alae keokeo*.....R
Hawaiian gallinule, *Gallinula galeata Sandwicensis* Streets. *Alae ula*.....R

INDIGENOUS

Black-crowned night heron, *Nyctocorax nyctocorax griseus* Bodd.....F

NATURALIZED

Rice bird, *Munia nisoria punctata* Temm.....C
English sparrow, *Passer domesticus* L.....C
Mynah bird, *Acridotheres tristis* L.....C
Skylark, *Alauda arvensis* L.....F
Chinese reed warbler, *Trochalopterum canorum* L.....C
Chinese turtle dove, *Turtur Chinensis* Scop.....C
Australian alae, *Alae iwi*, *Porphyrio melanotus* Newton.....R

*Explanation of Symbols*

H—herbaceous; annual.
S—shrubby.
A—arborescent.
P—perennial.
V—liana habit.
C—common.
F—frequent.
R—rare.

## 5. REPRESENTATIVE PLANTS OF THE VALLEY FLOOR

### GROUP I. ENDEMIC

*Ia. Hydrophytes*

*Hibiscus Youngianus* Gaud.....HSF

*Ib. Mesophytes*

*Nama Sandwicensis* Gray.....HF
*Sicyos cucumerina* Gray.....HR
" *pachycarpa* Hook. & Arn...HR
*Solanum aculeatissimum* Jacq....SF

*Ic. Xerophytes*

*Abutilon incanum* G. Don.....HSF
*Chenopodium Sandwicheum* Moq..HSF
*Erythraea sabaeoides* Gray.....HF
*Jacquemontia Sandwicensis* Gray.HVF

*Id. Parasites*

*Cuscuta Sandwichiana* Chois.....HVF

*Ie. Pteridophytes*

*Ophioglossum concinnum* Brack...F

### GROUP II. INDIGENOUS

*IIa. Hydrophytes*

*Commelina nudiflora* L.....HPC
*Kyllingia monocephala* Rottb.....HPC

*IIb. Mesophytes*

*Andropogon contortus* Roem. & Schult.....HPF
*Caesalpinia Bonducella* Fleming..VSPF
*Chrysopogon aciculatus* Trin.....HPC
*Cyperus pennatus* Lam.....HPC
*Ipomoea bona-nox* L.....HPVF
" *pentaphylla* L.....HVC
*Nicandra physaloides* Gaertn.....HF
*Panicum pruriens* Trin.....HPC
*Plumbago Zeylanica* L.....SPF
*Wikstroemia foetida* var. *Oahuensis* Gray.....SPF

*IIc. Xerophytes*

*Boerhaavia diffusa* L.....HSF
*Eleusine Indica* Gaertn.....HPC

*Erythrina monosperma* Gaud.....AR
*Ipomoea tuberculata* Roem. & Schult.....HPVC
*Panicum torridum* Gaud.....HC
*Sida fallax* Walp.....HSC
" *rhombifolia* L.....HSC
*Tephrosia piscatoria* Pers.....SPF
*Tribulus cistoides* L.....SPF
*Waltheria Americana* L.....SC

IId. *Pteridophytes*

*Ceropteris calomelaena* Link.....C
" *ochracea* Robins.....C
*Dryopteris propinqua* Gilb.....C
*Microlepia strigosa* Presl.....C
*Nephrolepis cordifolia* Presl.....F
" *exaltata* Schott.....C
*Odontosoria Chinensis* J. Sm.....C

GROUP III. INTRODUCED BY THE PRIMITIVE HAWAIIANS

IIIa. *Hydrophytes*

*Alocasia macrorrhiza* Schott.....HPF
*Colocasia antiquorum* Schott.....HPC

IIIb. *Hygrophytes*

*Artocarpus incisa* L.....AC
*Eugenia Malaccensis* L.....AF
*Musa sapientum* L.....HPC

IIIc. *Mesophytes*

*Calophyllum inophyllum* L.....AF
*Cocos nucifera* L.....AC
*Cucurbita maxima* Duch.....HVR
*Hibiscus tiliaceus* St. Hil.....AC
*Ipomoea Batatas* L.....HPVC
*Lagenaria vulgaris* Ser.....HVR
*Saccharum officinarum* L.....HPC
*Thespesia populnea* Correa.....AF

IIId. *Xerophytes*

*Morinda citrifolia* L.....AC
*Pandanus odoratissimus* L.....AC

GROUP IV. PLANTS NATURALIZED SINCE THE ADVENT OF EUROPEANS

IVa. *Hydrophytes*

*Arundo Donax* L.....HPF
*Coix lachryma* L.....HPC
*Panicum barbinode* Trin.....HC
*Sagittaria sagittifolia* L.....HC

IVb. *Hygrophytes*

*Coffea arabica* L.....AF
*Eugenia Jambos* L.....AC
*Physalis Peruviana* L.....HPC

IVc. *Mesophytes*

1. Trees and Shrubs

*Bixa Orellana* L.....F
*Carica Papaya* L.....F
*Cassia chamaecrista* L.....F
" *laevigata* Willd.....F
" *occidentalis* L.....C
*Cestrum diurnum* L.....F
*Citrus* spp.....F
*Eugenia Jambolana* Lam.....C
*Jatropha Curcas* L.....R
*Leucaena glauca* Benth.....AC
*Melia Azedarach* L.....AC
*Mimosa pudica* L.....HPSR
*Mammea Americana* L.....AF
*Psidium Cattleyanum* Sab.....AC
" *Guayava* L. and vars.....ASC
*Ricinus communis* L.....SAC
*Spondias dulcis* L.....AF
*Terminalia Catappa* L.....AC

2. Herbaceous Perennials

*Bambusa vulgaris* Schrad. & Wendl.....F
*Canna Indica* L.....C
*Cajanus Indicus* Spreng.....C
*Crotalaria fulva* Roxb.....C
" *saltiana* Andr.....C
" *spectabilis* Roth.....C
*Cynodon Dactylon* Pers.....C
*Cyperus rotundus* L.....C

*Echinochloa Crus-galli* (L.) Beauv. . . . . C
*Medicago apiculata* Willd. . . . . F
" *denticulata* Willd. . . . . F
" *Indica* All. . . . . F
" *intertexta* Mill. . . . . F
" *lupulina* L. . . . . C
*Mirabilis Jalapa* L. . . . . C
*Panicum barbinode* Trin. . . . . C
*Paspalum conjugatum* Berg. . . . . C
*Taraxacum officinale* Weber. . . . . R
*Thunbergia alata* Boj. and var. *aurantiaca* Ktz. . . . . F
*Verbena Bonariensis* L. . . . . C

3. Annual Herbs

*Asclepias Curassavica* L. . . . . F
*Bothriospermum tenellum* F. & M. . F
*Brassica campestris* L. . . . . R
*Cuphea hyssopifolia* H. B. K. . . . . R
*Erigeron albidus* Gray . . . . . F
" *Canadensis* L. . . . . C
*Euphorbia geniculata* Ort. . . . . C
" *pilulifera* L. . . . . C
*Fleurya interrupta* Gaud. . . . . R
*Franseria tenuifolia* Gray . . . . . F
*Malva rotundifolia* L. . . . . C
*Oxalis corniculata* L. . . . . F
" *Martiana* Zuccar. . . . . C
*Peucedanum graveolens* Benth. & Hook. . . . . F
*Plantago major* L. . . . . R
*Siegesbeckia orientalis* L. . . . . F

4. Vines

*Abrus precatorius* L. . . . . F
*Basella rubra* L. . . . . R
*Cardiospermum Halicacabum* L. . . C
*Clerodendron fragrans* Vent. . . . . F
*Clitoria Ternatea* L. . . . . F
*Convolvulus* spp. . . . . C
*Dolichos Lablab* L. . . . . C
*Ipomoea chryseides* Ker-Gaul. . . . . F
*Paederia foetida* L. . . . . C
*Passiflora foetida* L. . . . . F

IV*d. Xerophytes*

1. Trees and Shrubs

*Acacia Farnensiana* Willd. . . . . C
*Cassia occidentalis* L. . . . . C
*Casuarina equisetifolia* L. . . . . F
*Eucalyptus* spp. . . . . C
*Indigofera Anil* L. . . . . C
*Nicotiana glauca* Grah. . . . . F
*Opuntia megacantha* Salm . . . . . C
*Phoenix dactylifera* L. . . . . F
*Prosopis juliflora* L. . . . . C

2. Herbaceous Perennials

*Abutilon* spp. . . . . C
*Amaranthus spinosus* L. . . . . C
*Desmodium uncinatum* DC. . . . . C
*Drymaria cordata* Willd. . . . . F
*Momordica charantia* L. . . . . FV
*Phaseolus semierectus* L. . . . . C
*Priva aspera* H. B. K. . . . . R
*Sida spinosa* L. . . . . F
*Solanum Sodomeum* L. . . . . C
*Stachytarpheta dichotoma* Vahl. . . C
*Xanthium Strumarium* L. . . . . C

3. Annual Herbs

*Ageratum conyzoides* L. . . . . C
*Anagallis arvensis* L. . . . . F
*Bidens pilosa* L. . . . . C
*Chaetochloa verticillata* Scribn. . . . C
*Chenopodium album* L. . . . . C
" *hybridum* L. . . . . E
" *murale* L. . . . . F
*Datura Stramonium* L. . . . . F
*Eleusine Aegyptiaca* Pers. . . . . C
" *Indica* Gaertn. . . . . C
*Emilia flammea* Cass. . . . . R
*Erodium cicutarium* L'Her. . . . . F
*Euxolus viridis* Moq. . . . . F
*Gynandropsis pentaphylla* DC. . . . C
*Malvastrum tricuspidatum* Gray. . C
*Portulaca oleracea* L. . . . . C
*Rumex Acetocella* L. . . . . F
*Senebiera didyma* Pers. . . . . F
*Sonchus oleraceus* L. . . . . C
*Stachys arvensis* L. . . . . F
*Vernonia conyzoides* L. . . . . C

It will be noted that this list, which includes practically all of the important species of this region, comprises the following groups:

| | Species | | |
|---|---|---|---|
| Endemic | 11 | Hydrophytes | 9 |
| Indigenous | 29 | Hygrophytes | 6 |
| Introduced by primitive Hawaiians | 15 | Mesophytes | 82 |
| Introduced since the advent of Europeans | 115 | Xerophytes | 56 |
| | | Vines or lianas | 18 |
| | | Pteridophytes | 8 |

## 6. MANOA STREAM

The surface drainage waters of Manoa escape as a single small and fluctuating brook, known as Manoa Stream. A very considerable percentage of the Manoa drainage makes its way to the sea through

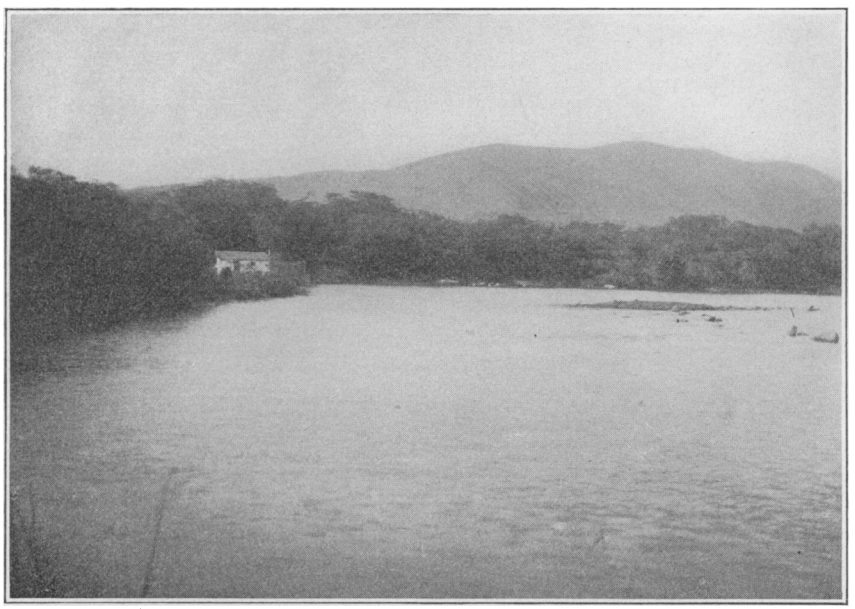

FIG. 7. Manoa stream near its mouth. The trees are *Prosopsis juliflora*. In the distance is the west lateral ridge, with Round Top and Tantalus showing distinctly.

subterranean channels; this is a condition universal throughout the islands. Manoa Stream is fed by numerous tributaries, which enter

the head of the valley over beautiful waterfalls. There is also a series of springs along the foot of the cliffs at the head of the valley, which contribute their waters to the stream. Other springs, notably those on the grounds of the Kawaiahao Seminary and Punahou Academy, occur on the valley floor.

The ten contributory branches of the stream are freshet in character and very intermittent in their flow. The stream proper is never wholly dry. After the rare protracted droughts it becomes very low, and its branches cease to flow. The upper course of the stream lies in the middle of the valley. The lower course has been strongly deflected against the east foothill, presumably by the outpourings of lava and other volcanic material from the craters in the west foothill. The stream leaves the valley at the extreme eastern side, hugging the base of the east foothill, where it has carved a small narrow canyon through the thick beds of ancient flow lava.

The stream is marked throughout its course by vegetation characteristic of streamways and swampy places. Due to the general utilization of the stream waters for irrigation, the swampy areas and *loi kalo* (*taro* patches), adjacent to the stream itself are here considered as a part of this ecologic zone. The vegetation of the streamway is nowhere sharply differentiated from that of the valley floor. In numerous instances the species that grow most luxuriantly along the stream are also forms most abundant on the valley floor.

From the ecologic standpoint the stream is at present a factor of minor importance in determining the phytogeography of Manoa. It undoubtedly had a more prominent rôle in early times, before the valley floor was overrun by introduced vegetation. One of the influences of the stream is as an agent for the dissemination of seeds. Frequently the seeds of montane species are carried to lower levels, where they occasionally establish themselves. It is extremely significant, however, that there has been no general seaward migration of montane species via the stream; in general the forests have retreated up stream.

## 7. PLANTS ABUNDANT ALONG OR CHIEFLY CHARACTERISTIC OF THE MANOA STREAM AND ITS TRIBUTARIES, INCLUDING ADJACENT SWAMPS AND TARO-PATCHES

### GROUP I. ALGAE

*Anabaena confervoides* Reinsch.
" *variabilis* Kuetz.
*Aphanothece repens* A. Br.
Bulbochaeta spp.
*Calothrix fusca* Bornet.

*Chamaesiphon curvatus* Nordst.
*Chara coronata* var. *leptosperma*.
" *forma Oahunesis* A. Br.
" *gymopus* var. *armata* Nordst.
*Cladophora Nordstedii* De T.
*Closteriopsis longissima* Lemm.
*Coleochaete irregularis* Pringsh.
" *orbicularis* Pringsh.
*Conferva bombycina* var. *minor* Wille.
" *Sandwicensis* Ag.
*Dactylococcus infusionum* var. *minor* Nordst.
*Dictyosphaerium pulchellum* Wood.
*Draparnaldia macrocladia* Nordst.
*Gloeothece fuscolutea* Naeg.
*Gonium sociale* Warm.
*Hydrodictyon reticulatum* Lagerh.
*Lyngbya aestuarii* Liebman.
" *distincta* Schm.
" *rivularium* Gomont.
*Merismopedium glaucum* Naeg.
*Nitella Havaiensis* Nordst.
*Nostoc commune* Vaucher.
" *paludosum* Kuetz.
" *piscinale* Kuetz.
" *punctiforme* Hariot.
*Raphidium polymorphum* Fres.
*Rivularia natans* Welw.
*Scenedesmus quadricauda* Breb.
*Scytonema crispum* Bornet.
Spirogyra spp.
*Stigeoclonium Falklandicum* Kuetz.
*Stigonema aerugineum* Tilden.
" *ocellatum* Thuret.
*Ulothrix minulata* Kuetz.
" *subtilis* Kuetz.
*Xenococcus Kerneri* Hansg.
*Zygnema spontaneum* Nordst.

GROUP II. PTERIDOPHYTES

*Marsilea villosa* Kaulf.....F, endemic.
" *crenulata* Desv.....R, "
Azolla sp.....F, recent introduction.

GROUP III. SPERMATOPHYTES

IIIa. *Indigenous*

*Aster divaricatus* Torr. & Gray...HPF
*Bidens chrysanthemoides* Michx...HF
*Cladium leptostachyum* Nees & Meyen.....HPL
*Commelina nudiflora* L.....HPC
*Cyperus auriculatus* Nees.....HPL
" *laevigatus* L.....HPF
*Eleocharis obtusa* Schultes.....HPL
*Ipomoea bona-nox* L.....HPVF
" *reptans* Poir.....HPVF
*Jussiaea villosa* Lam.....HPC
*Kyllingia monocephala* Rottb.....HPC
*Naias major* All.....HC
*Polygonum glabrum* Willd.....HF
*Poa annua* L.....HF
*Potamogeton fluitans* Roth.....HPF
" *pauciflorus* Pursh...HPF
*Scirpus lacustris* L.....HPF
" *maritimus* L.....HPR
*Zingiber Zerumbet* Ros.....HPF

IIIb. *Introduced by the Primitive Hawaiians*

*Aleurites Moluccana* Willd.....AF
*Alocasia macrorrhiza* Schott.....HPF
*Colocasia antiquorum* Schott.....HPC
*Eugenia Malaccensis* L.....AF
*Hibiscus tiliaceus* L.....AC
*Musa sapientum* L.....HPF

IIIc. *Introduced Since the Advent of Europeans*

*Coix lachryma* L.....HPC
*Canna Indica* L.....HPC
*Cyperus rotundus* L.....HPC
*Echinochloa colonum* Link.....HPC
*Eugenia Jambos* L.....AC
*Hydrocotyle Asiatica* L.....HC
" *verticillata* Thunb....HC
*Leucaena glauca* Benth.....SC
*Lemna minor* L.....HC
*Nasturtium officinale* R. Br.....HF
*Mazus rugosus* Lour.....HF
*Panicum barbinode* Trin.....HC
*Pithecolobium Saman*.....AF
*Psidium Guayava* L.....SC
*Sagittaria sagittifolia* L.....HC

## 8. THE TALUS ZONE

Between the valley floor and the valley walls lies an intermediate physiographic and floristic zone, which may be designated as the talus zone. This zone comprises, as its name indicates, the talus deposits at the foot of the valley wall and resting upon the floor. It varies in width from approximately 100 to 1,000 feet. The slope averages 10–15°, as contrasted, on the one hand, with the 40° slope of the wall, and, on the other, with the nearly flat floor. The soil of the talus zone varies considerably in nature in various parts of the valley—in some places it is fine-grained lava soil; in others, coarse volcanic ash and cinders; and in others the ground is littered with massive boulders that have been dislodged from the heights above. It is probable that the talus slope is not, in cross-section, wholly composed of talus; the surface layers are of debris, and below them are the ancient lava-sheets of the valley walls. This situation is revealed by the little streamways that are cut through the talus zone.

The dominant plant of the Manoa talus zone is the guava, *Psidium Guayava*. Secondary species are: *Lantana Camara*, *Paspalum conjugatum*, *Andropogon contortus*, *Verbena Bonariensis*, *Psilotum nudum*, *Morinda citrifolia*, *Nephrolepis exaltata*, *Solanum sodomeum*, Convolvulus spp., *Cassia occidentalis*, *Opuntia megacantha*, *Waltheria Americana*, etc. The talus zone, like the valley floor upon which it rests, is covered almost exclusively with ruderal vegetation. Arborescent forms are infrequent; vigorous and drought-resistant herbaceous-woody shrubs are the prevailing types.

In primitive times the talus zone of the upper valley was completely clothed with native trees, the species being those of the lower forest zone. The forest retreated before the incursions of man and wild live-stock, and exposed the talus zone to the invasions of foreign vegetation. The hilo grass (*Paspalum conjugatum*) has been notably pernicious, as it forms a dense sod and effectually prevents the native species from reseeding themselves.

The talus zone of the lower valley probably has been always more or less xerophytic in character. Many of the indigenous or endemic xerophytes of Hawaii have become extinct or are now upon the verge of extinction. This condition is pronounced in several leeward localities on the various islands—Hawaii, Maui, Molokai, Kauai—and undoubtedly obtained in Manoa.

## 9. THE VALLEY WALLS OR LATERAL RIDGES

The Manoa portal opens to the southwest and is bounded on east and west by the plainward terminations of its two irregularly sculptured lateral ridges. These terminal areas of the ridges may be designated as foothills; that on the east is the Manoa-Palolo foothill; that on the west is the Roundtop foothill.

The ridges extend from the coastal plain up to the main summit-ridge of the range, which here has an average elevation of 2,300 feet. Like all the ridges which define the Hawaiian valleys, these are the remnants of an original volcanic dome. The lower or foothill ends of the ridges are sufficiently bare of vegetation to reveal the laminated series of basaltic lava flows, of which they are mainly composed.

Each lateral ridge may be divided by vertical lines into three sections or areas:

1. The terminal or outlier foothill, which fronts upon and rests upon the coastal plain.

2. The transition or intermediate "knife-edge" region.

3. The mountainward region, wherein the ridge connects with or springs from the main summit ridge.

*The Manoa-Palolo or East Foothill.*—This, viewed from above, is a fan-shaped mass, with the expanded portion abutting upon the coastal plain. The upper slope narrows to a high (1,200 feet) apical region. The seaward slope of the foothill has an angle of about 8°; the valley wall is abrupt, rising at about 40°. The origin and physiography of the foothill is due to the remarkably localized distribution of the rainfall, as has been referred to in a previous section of the paper. The rainfall on the foothill itself is comparatively slight. Therefore erosion has advanced much more in the mountainward districts, and has left the foothill as a more or less isolated and xerophytic outlier. In the Waianae district, on Oahu, are found the culminating stages in the isolation of the foothill from the main range.

*The Roundtop Foothill.*—The lateral ridge which constitutes the western wall or boundary of Manoa Valley terminates in Roundtop (*Uala-kaa*). This whole ridge is distinguished by a series of ancient explosive volcanoes, of which Roundtop is the most seaward and Mount Tantalus (*Puu Ohia*) is the highest and most conspicuous. The highest points are Roundtop, 1,000 feet, Sugarloaf 1,400 feet, and Tantalus 2,013 feet. Tantalus has a well-defined crater; the craters of the other cones are either eroded away, or hidden under

volcanic *ejecta*. There are a number of lesser, unnamed craters on the west ridge, and on the lower valley floor, which are very obscure, and not of phytogeographic significance.

The three named craters in prehistoric times discharged vast quantities of volcanic ashes and cinders. This material was deposited in thick blankets over the local topography, obliterating the original land features, and masked the irregularities which had been produced

FIG. 8. View on the slopes of Round Top, showing garden patches, papaia trees and general physiography.

by erosion. Thus the surface of the Roundtop Foothill is much smoother than that of the Manoa-Palolo foothill. On the latter the surface material is the ponderous basaltic sheet lava of which the original volcanic dome was composed; on the Roundtop foothill the surface material is a secondary volcanic product—lapilli—light in weight, very porous, and produced within relatively recent geologic times.

This difference in the nature of the surface material has resulted in a striking difference in the agricultural utilization of the two foot-

hills. The eastern one is so rocky and rugged that it is untillable, and is used only as cattle land. The steeper slopes are covered with various introduced weeds, which have been enumerated. The Roundtop foothill, on the contrary, is rich volcanic ash, thoroughly drained, easily cultivated, and giving high yields of such crops as sweet potatoes, papaias, onions, carrots, and various other garden vegetables. There are many little garden patches on the upper slopes of Roundtop, cultivated by Portuguese, Hawaiians, Orientals, and others. The lower slopes are occupied by residences.

The outstanding ecological characteristics of the foothill region are:

1. A strong tendency toward xerophytism, indicated by the presence of many xerophytes and semi-xerophytes.
2. Brilliant insolation, due to the fact that the foothills lie seaward of the mountain cloud-cap, and under a sky which is largely cloudless.
3. Exposure to the winds, both trade and kona, owing to the smooth topography.
4. No surface water, except during and immediately after rains.
5. Topography has permitted wild live stock to overrun the foothills and to exterminate most of the native vegetation.
6. Invasion by a great variety of foreign weeds, the woody or herbaceous woody type being dominant.

## 10. PLANTS OF THE FOOTHILL AND ITS WALLS

Most of the plants which occur upon the foothill and its walls also occur on the valley floor; they are chiefly naturalized xerophytic ruderals.

GROUP I. ENDEMIC

*Cassia Gaudichaudii* Hook. & Arn. . . . . SF
*Chenopodium Sandwicheum* Moq. . HSF
*Lepidium Oahuense* Cham. & Schl. . . . . HPF
*Lipochaeta connata* DC. var. *decurrens* Hillebr. . . . . HPSR
*Nama Sandwicensis* Gray . . . . . HF
*Neraudia melastomaefolia* Gray . . SF
*Phyllanthus Sandwicensis* Mueller . . . . . SR
*Reynoldsia Sandwicensis* Gray . . . AR
*Scaevola Gaudichaudii* Hook. & Arn. . . . . SR
*Solanum aculeatissimum* Jacq. . . . SF

GROUP II. INDIGENOUS

*Andropogon contortus* Roem. & Schult. . . . . HPF
*Boerhaavia diffusa* L. . . . . HSF
*Chrysopogon aciculatus* Trin. . . . . HPC
*Cyperus polystachys* Rottb. . . . . HPR
*Daucus pusillus* Michx. . . . . HR
*Dracaena aurea* Mann. . . . . AR
*Euphorbia cordata* Meyen . . . . . HPF
*Gnaphalium luteo-album* L. . . . . HF
" *purpureum* L. . . . . HR
*Ipomoea pentaphylla* Jacq . . . . . HVF
" *tuberculata* Roem. & Schult. . . . . HPVF
*Osteomeles anthyllidifolia* Lindl. . . SVF

*Panicum pruriens* Trin.....HPC
" *torridum* Gaud.....HC
*Phaseolus semierectus* L.....HPC
*Plectranthus parviflorus* Willd....HC
*Plectronia odorata* Benth & Hook..SF
*Pilea peploides* Hook. & Arn.....HF
*Sida cordifolia* L.....HPC
" *rhombifolia* L.....HPC
" *fallax* Walp.....HPC
*Solanum nodiflorum* Jacq.....HR
*Stenotaphrum Americanum* Schrank.....HPF
*Waltheria Americana* L.....HPC
*Wikstroemia uva-ursi* Gray.....HPSR

GROUP III. INTRODUCED SINCE THE ADVENT OF EUROPEANS

*Acacia Farnensiana* Willd.....SC
*Ageratum conyzoides* L.....HC
*Argemone Mexicana* L.....HC
*Asclepias Curassavica* L.....HF
*Bidens pilosa* L.....HC
*Bryophyllum calycinum* L.....HPF
*Cardamine hirsuta* L.....HF
*Cassia occidentalis* L.....HPC
*Cenchrus calyculatus* Cav.....HPR
" *echinatus* L.....HC
*Centaurea melitensis* L.....HF
*Cestrum diurnum* L.....AR
*Chenopodium album* L.....HC
*Clerodendron fragrans* Vent.....HPVR
*Crepis Japonica* Benth.....HC
*Crotalaria fulva* Roxb.....HPC
" *saltiana* Andr.....HPC
" *spectabilis* Roth.....HPC
*Cynodon Dactylon* Pers.....HPF
*Cyperus rotundus* L.....HPC
*Desmodium uncinatum* DC.....HC
*Eleusine Indica* Gaertn.....HC
*Erigeron albidus* Gray.....HC
" *Canadensis* L.....HC
*Eugenia Jambolana* L.....AR
*Euxolus viridis* Moq.....HF
*Indigofera Anil* L.....HPC
*Lantana Camara* L.....SC
*Leucaena glauca* Benth.....SF
*Mirabilis Jalapa* L.....HPF
*Momordica charantia* L.....HPVR
*Nicotiana glauca* Grah.....AR
*Opuntia megacantha* Salm.....HPC
*Paspalum conjugatum* Berg.....HPC
*Passiflora foetida* L.....HPVF
*Paederia foetida* L.....HPC
*Phyllanthus Niruri* L.....HF
*Pithecolobium Saman* Benth.....AF
*Plantago major* L.....HR
*Psidium Guayava* L.....SC
*Prosopis juliflora* L.....AC
*Ricinus communis* L.....SC
*Salvia occidentalis* Swartz.....HR
*Sonchus oleraceus* L.....HC
*Stachys arvensis* L.....HF
*Stachytarpheta dichotoma* Vahl....HPC
*Solanum Sodomeum* L.....SF
*Verbena Bonariensis* L.....HPC

## 11. THE TRANSITION REGION

This term is used to designate the "knife-edged" portion of the lateral ridge, which lies between the foothill and the mountainward termination of the ridge in the main range. The mountainward limit of the foothill area is clearly defined by an eminence or little peak; beyond this the ridge abruptly descends and narrows. The conspicuous vertical erosion which has produced the "knife-edged" crest so characteristic of this portion of the ridge, indicates clearly the heavy rainfall to which it is subjected. The crest of the foothill is a broad, sloping, triangular plane; the crest of the transition or inter-

mediate region is very narrow, in many places being only 2 or 3 feet in width. The valley walls of the foothill are relatively smooth and unfurrowed; the walls of the transition ridge are deeply fluted, with numerous alcoves.

The Transition Region marks the area intermediate, in ecologic features, between the high, humid ridges of the rain-forest proper, and the low, arid foothills with their covering of xerophytic and semi-xerophytic vegetation. It marks with considerable accuracy the usual seaward limit of the summit-ridge cloud-cap.

On the west ridge there is a marked discrepancy between the situations of the topographic transition region and the vegetational transition region. These two do not coincide; the topographic transition region lies two miles mountainward of the vegetational transition region. This difference is due to the presence of the Tantalus series of volcanic craters along the west ridge; these have pushed the topographic region much further mountainward than it otherwise would have occurred.

On the east ridge practically none of the normal vegetation of the lower or middle forest zones occurs seaward of the Transition Region. On the west ridge Mount Tantalus rises to a height of 2,000 feet on the seaward side of the topographic Transition Region, and supports a luxuriant lower- and middle-forest flora.

The east transition ridge is but 1,200 feet high, at its lowest point, whereas the west transition ridge is about 1,700 feet high. The rain-forest, which on the east ridge does not extend beyond the Transition Region, on the west ridge covers, not only the "transition" region, but also the mountainward half of the Tantalus mass. This condition clearly illustrates that rainfall and not topography determines the lower limits of the montane forest.

### 12. THE VALLEY HEAD

The head of Manoa Valley is an expanded amphitheater of erosion, rimmed by abrupt and deeply dissected walls. From the standpoint of plant life it is an ecologic complex, comprising the following elements:

1. The upper valley floor, already described.
2. A zone of broad, gentle, grassy slopes, lying above the valley floor and below the *kukui* zone. Many of these ridges are knife-edged and precipitous in their upper courses, and separate deep, narrow ravines (700–1,400-ft. contours).

3. A series of cliffs or palis, which lie between the ridges, and are more or less covered with vegetation. These cliffs are 200–300 feet high, and are cut at fairly regular intervals by V-shaped gorges and hanging valleys, from the mouths of which waterfalls issue and drop down the face of the cliffs.
4. Above the cliffs is a series of hanging valleys, separated from one another by steep ridges. These ravines have an average elevation of 1,400–2,000 feet and open above the face of the precipice. They extend abruptly back and up to the main summit ridge, a distance of .50–.75 mile.
5. The summit ridge.

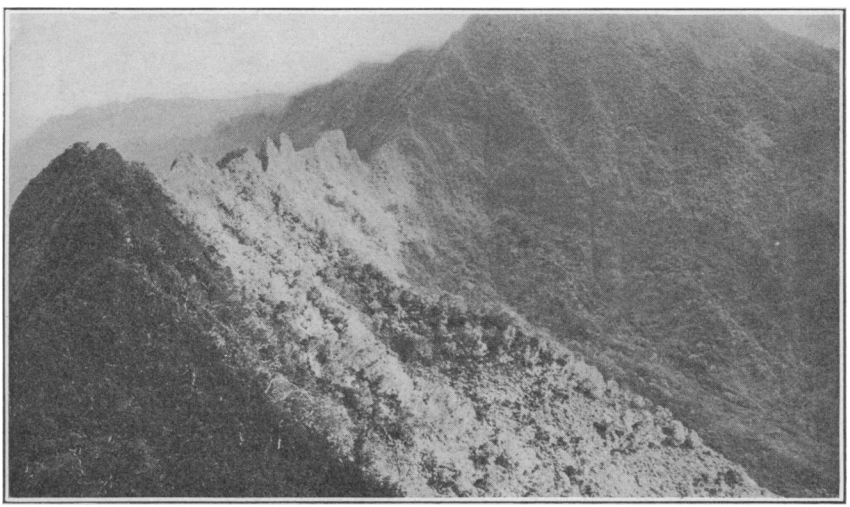

FIG. 9. Typical physiography of valley head, summit ridge and peaks. Note ravines and hanging valley formation.

The general structure of Manoa Valley, with reference to plant geography, is fundamentally the same as that of the other valleys along the leeward flanks of the Koolaus. However, variations of marked phytogeographic significance may be noted. Nuuanu Valley, for example, has cut completely through the range, and so its head is much more windswept than that of Manoa. The difference in the windiness of the heads of these two valleys has produced an observable difference in their respective vegetations, that of Nuuanu being

conspicuously wind beaten. The heads of the valleys in the Punaluu region support a much finer type of forest than that of Manoa, for the former region has been practically free from the ravages of wild goats and other herbivores, and the forest is in its primitive condition. The Manoa Valley head occupies an ecologic position somewhat intermediate between the extremely arid and depleted valleys toward Makapuu Point, and the hygrophytic valleys of the central part of the range.

### 13. PU'U PUEO (PUPIA)

The upper floor is bifurcated by a ridge which emanates from the main summit ridge and which terminates in a green grassy hill known as Puu Pueo, the Owl Hill. This median ridge is about 2 miles long, its lowest point is 300 feet above sea-level, and Puu Pueo rises 500 feet above the valley floor. Due to the extensive erosion in the region mountainward of the hill, the ridge is conspicuously saddle-shaped, when viewed from the side.

Puu Pueo was at one time, like the region immediately adjacent to it, densely covered with the mantle of the lower forest; the ravages of wild goats and cattle, wood-cutters, and in recent times, dairy cattle, have stripped from the hill practically all of its forest growth. The principal plant now is the ubiquitous *Paspalum conjugatum;* other plants occurring here and there upon the hill are *Scaevola Chamissoniana*, *Acacia Koa*, *Microlepia strigosa*, *Cordyline terminalis*, *Clermontia macrocarpa*, *Pipturus albidus*, *Sadleria Hillebrandii*, *Osteomeles anthyllidifolia*, etc.

This ridge originally extended down the valley much further than it does at present. It is not unlikely that there were other ridges lying parallel with it, and that the physiography was considerably more complex than that of Manoa today. The present broad floor may be the result of the almost total elimination of several of these ancient ridges. Under this hypothesis the plant life of the valley under these early conditions was probably more diversified and precinctive than it is at present. Erosion has caused an infinitely gradual shifting of plant groups and zones. Projecting this vision into the future, the head of the valley will become increasingly larger, all contours more regular, and the life conditions more mesophytic. Puu Pueo will have vanished and the foothills will have been completely isolated as outliers, with low open gaps into Nuuanu and

Palolo. The foreign lowland vegetation will dominate the entire floor and its adjacent slopes.

### 14. THE MANOA LOWER FOREST OR KUKUI ZONE

As one views the upper portion of the valley, from the floor or mouth, the most conspicuous plant zone is the *kukui* or lower forest. This is due to the fact that the *kukui* foliage is pale silvery green, quite distinct from the yellow green of the grass lands or the heavy somber green of the rain-forest. The *kukui* groves form a broad, more or less broken band across the head of the valley.

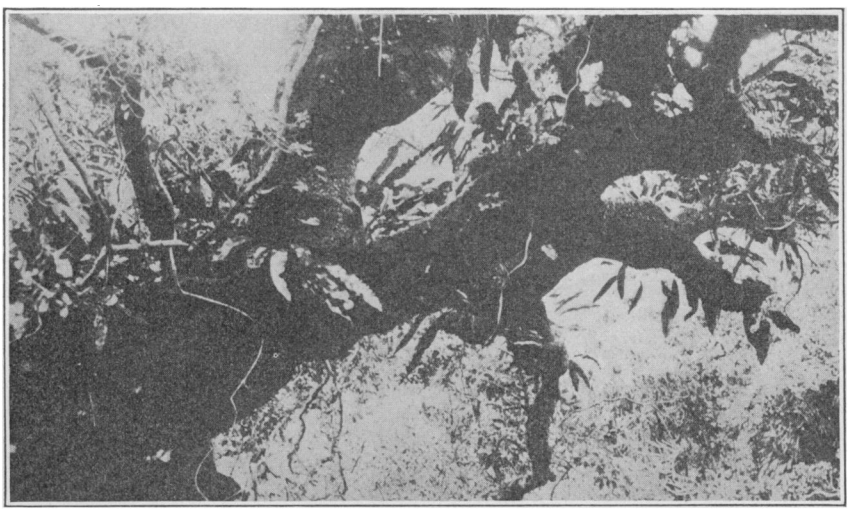

FIG. 10. *Kukui* tree in lower forest zone, covered with epiphytic plants, chiefly pteridophytes, bryophytes and lichens.

The *kukui* or Candle-nut Tree, *Aleurites Moluccana* Willd., is an euphorbiaceous tree. It was probably introduced by the primitive Hawaiians from the South Pacific, where it is abundant. It is now thoroughly established in the lower forest zone throughout the Hawaiian Islands, and is the dominant tree in many regions. It attains a height of 40–60 feet, but is usually about 30 feet high, with a broad, dome-shaped crown.

In Manoa the *kukui* occupies an irregular horizontal zone, lying across the head and around the sides of the valley, mainly between

the 300- and 1,000-ft. contour lines. Along its lower fringe or level the *kukui* gives way to various species of woody or shrubby plants, conspicuous among which are: *Psidium Guayava*, *Lantana Camara*, *Osteomeles anthyllidifolia*, *Eugenia Malaccensis*, *Cordyline terminalis*, *Verbena Bonariensis*, *Hibiscus tiliaceus*, *Pandanus odoratissimus*, *Melia Azedarach*, Cassia spp., *Leucaena glauca*, *Bambusa*, etc. Along its upper border or level it is more or less abruptly replaced by such forms as *Acacia Koa*, *Metrosideros polymorpha*, *Ilex Sandwicensis*, Pelea spp., Pittosporum spp., *Cheirodendron Gaudichaudii*, and other rain-forest forms.

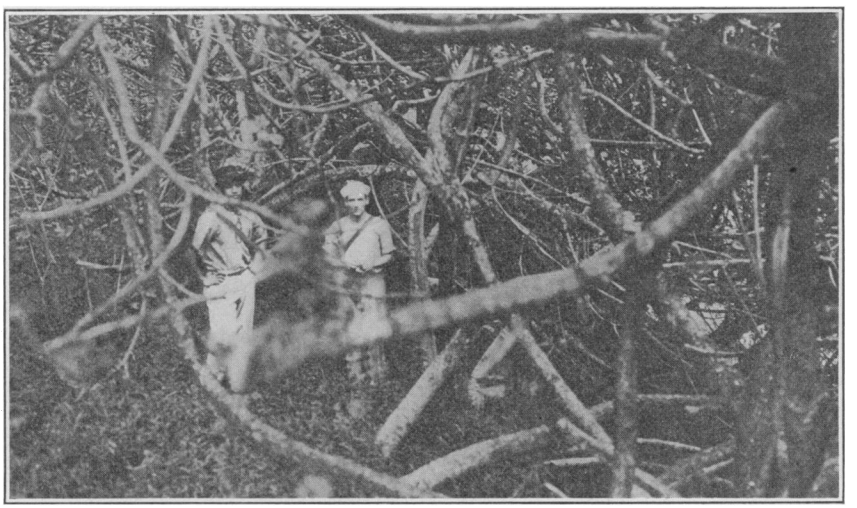

FIG. 11. In a Manoa *hau* (*Hibiscus tiliaceus*) jungle. The foliage canopy is thirty feet above the men.

Along the lateral walls of Manoa the *kukui* extends seaward until it reaches a point whereat the increasing xerophytism, and the devastations of wild goats and other pests, have inhibited its growth. There is ample evidence that in early times the *kukui* forests of Manoa extended much further seaward along the walls and floor of the valley than they do at present. There has been extensive encroachment by man and his live-stock upon all the native forests.

The *kukui* is a moisture-loving tree and in Manoa reaches its finest development in the little vales or alcoves which furrow the

walls and head of the valley. It does not grow upon the exposed ridges which separate these alcoves from one another, nor upon the crests of the lateral ridges, but nestles in the alcoves. On the lateral walls it ascends to within 100 feet of the crest of the ridge. At the valley head the rain-forest rises 2,000 feet above the upper limits of the kukui zone.

The chief botanical features of the Manoa lower forest are as follows:

1. The lower forest presents a series of life conditions much less rigorous than those of the rain-forest. The slope, soil, protection from wind, and mean temperature, are all more favorable for plant development than are those same factors in the rain-forest region.

2. The lower forest, in the days of the primitive Hawaiians, was an important zone for the raising of crop plants. Twelve species were cultivated in little clearings here and there along the skirts of the lower forest. This zone was subjected to the direct and indirect effects of human utilization to a much greater degree than was the rain-forest. In ancient Hawaii the rain-forest was not much frequented by the natives—they made occasional visits for birds, canoe timbers, etc.

3. The physiognomy of the lower forest zone has been strikingly modified by introduced Hawaiian crop plants, particularly *Aleurites Moluccana*, *Cordyline terminalis*, and *Eugenia Malaccensis*. The former has become the dominant tree, and in parts of Manoa and elsewhere in the islands forms pure stands of considerable magnitude.

4. The lower boundary of this zone is undoubtedly at present at a much higher level than ever before in the history of the islands. In other words, the forested montane area is continuously diminishing; the forest margin is slowly creeping up the mountains. In geological time this movement was due to slow subsidence (according to the subsidence theory); in recent times it has been tremendously accelerated by herbivorous animals.

5. The undergrowth of herbaceous and herbaceous-perennial vegetation is much richer in the lower forest than in the rain-forest. The pteridophyte representation is much greater, however, in the latter; the Manoa rain-forest possesses 93 species, the lower forest has 40 species.

6. The lower forest tends to be more or less open, whereas the rain-forest is a completely closed association. Epiphytic vegetation is much more abundant in the rain- than in the lower forest.

## 15. REPRESENTATIVE PLANTS WHICH EXCLUSIVELY OR IN MOST PART INHABIT THE MANOA LOWER FOREST ZONE, KUKUI ZONE

### GROUP I. ENDEMIC

#### *Trees*

*Charpentiera ovata* Gaud. . . . . C
*Clermontia macrocarpa* Gaud. . . . . C
*Dracaena aurea* Mann. . . . . R
*Elaeocarpus bifidus* Hook. & Arn. . . . C
*Eugenia Sandwicensis* Gray . . . . . R
*Gardenia Brighamii* Mann . . . . . R
" *Remyi* Mann . . . . . R
*Maba Hillebrandii* Seem. . . . . R
*Ochrosia Sandwicensis* Gray . . . . . R
*Osmanthus Sandwicensis* Knobl. . . . . F
*Perrottetia Sandwicensis* Gray . . . . . F
*Pipturus albidus* Gray . . . . . C
*Rauwolfia Sandwicensis* A. DC. . . . . C
*Reynoldsia Sandwicensis* Gray . . . . . F
*Santalum Freycinetianum* Gaud. . . . . F
*Urera Sandwicensis* Wedd. . . . . F

#### *Shrubs and Herbaceous Perennials*

*Alyxia olivaeformis* Gaud. . . . . VC
*Eragrostis variabilis* Gaud. . . . . C
*Euphorbia Hookeri* Steud. . . . . F
" *multiformis* Hook. & Arn. . C
*Freycinetia Arnotti* Gaud. . . . . C
*Gahnia Beecheyi* Mann . . . . . F
" *globosa* Mann . . . . . F
*Gouldia coriacea* Hillebr. . . . . F
*Joinvillea adscendens* Gaud. . . . . R
*Kadua acuminata* Cham. & Schlecht. . F
" *cordata* Cham. & Schlecht. . . . F
*Lipochaeta connata* DC. var. *decurrens* Hillebr. . . . . R
*Lysimachia Hillebrandii* Hook. f. . . . . F
" *rotundifolia* Hillebr. . . . . R
*Osteomeles anthylidifolia* Lindl. . . . . C
*Rhynchospora thyrsoidea* Nees & Meyen . . . . . F
*Rollandia grandifolia* Hillebr. . . . . F
" *lanceolata* Gaud. . . . . F
*Scaevola Chamissoniana* Gaud. . . . . C
*Sida Meyeniana* Walp. . . . . F
*Smilax Sandwicensis* Kunth . . . . . VC
*Solanum Sandwicense* Hook. & Arn. . F
*Vaccinium penduliflorum* Gaud. var. *calycinum* Hillebr. . . . . R
*Wikstroemia foetida* var. *Oahuensis* Gray . . . . . F

#### *Herbs*

*Anoectochilus Sandwicensis* Lindl. . . . R
*Canavalia galeata* Gaud. . . . . VR
*Liparis Hawaiiensis* Mann . . . . . R

#### *Pteridophytes*

*Athyrium Poiretianum* Presl. . . . . F
*Asplenium Macraei* Hook. & Grev. . . F
*Cibotium Chamissoi* Kaulf. . . . . C
*Doryopteris decipiens* J. Sm. . . . . C
*Dryopteris nuda* Underw. . . . . F
" *rubiformis* Robins. . . . . F
" *stegnogrammoides* C. Chr. . R
*Polypodium Hillebrandii* Hook. . . . . R
*Sadleria Hillebrandii* Robins. . . . . F
" *polystichoides* Heller . . . . . R
*Polypodium pseudogrammitis* Gaud. . C

### GROUP II. INDIGENOUS

#### *Trees*

*Dodonaea viscosa* L. . . . . C
*Maba Sandwicensis* A. DC. . . . . C
*Pisonia umbellifera* Seem. . . . . C
*Plectronia odorata* Benth. & Hook. . . F

#### *Shrubs and Herbaceous Perennials*

*Adenostemma viscosum* Forst. . . . . C
*Caesalpinia Bonducella* Flem. . . . . R
*Dianella odorata* Blume . . . . . F
*Ipomoea insularis* Steud. . . . . C
*Kyllingia monocephala* Rottb. . . . . F
*Lythrum maritimum* H. B. K. . . . . F
*Oplismenus compositus* R. & Schult. . . C
*Panicum pruriens* Trin. . . . . C
*Phytolacca brachystachys* Moq. . . . . F
*Styphelia tameiameia* F. Muell. . . . . C
*Zingiber Zerumbet* Roscoe . . . . . C

*Herbs*

*Commelina nudiflora* L.....F
*Daucus pusillus* Michx.....R
*Solanum nodiflorum* Jacq.....C

*Pteridophytes*

*Adiantum capillus-veneris* L.....C
*Asplenium caudatum* Forst.....F
" *horridum* Kaulf.....C
" *lunulatum* Sw.....C
" *unilaterale* Lam.....C
*Dicranopteris linearis* Underw.....C
*Dryopteris cyatheoides* Kuntze.....C
" *Sandwicensis* C. Chr.....F
*Ceropteris calomelaena* Link.....C
" *ochracea* Robins.....C
*Coniogramme fraxinea* Diels.....C
*Dryopteris truncata* Kuntze.....F
*Lycopodium cernuum* L.....C
*Microlepia speluncae* Moore.....R
" *strigosa* Kaulf.....C
*Neottopteris Nidus* J. Sm.....C
*Odontosoria Chinensis* J. Sm.....C
*Pellaea ternifolia* Link.....F
*Phymatodes elongata* Presl.....C
" *Spectrum* Presl.....R
*Psilotum nudum* Griseb.....C
*Pteridium aquilinum* Kuhn.....F
*Pteris Cretica* L.....C
*Sadleria cyatheoides* Kaulf.....C
*Selaginella Menziesii* Spring.....C
*Tectaria cicutaria* Robins.....C
*Trichomanes Bauerianum* Endl.....F
" *humile* Forst.....F
*Vittaria rigida* Kaulf.....C

GROUP III. INTRODUCED BY THE PRIMITIVE HAWAIIANS

*Trees*

*Aleurites Moluccana* Willd.....C
*Broussonettia papyrifera* Vent.....F
*Eugenia Malaccensis* L.....C

*Shrubs and Herbaceous Perennials*

*Alocasia macrorrhiza* Schott.....C
*Colocasia antiquorum* Schott.....F
*Cordyline terminalis* Kunth.....C
*Curcuma longa* L.....R
*Dioscorea pentaphylla* L.....F
" *sativa* L.....C
*Musa sapientum* L.....C
*Piper methysticum* Forst.....R
*Tacca pinnatifida* Forst.....R
*Touchardia latifolia* Gaud.....F

GROUP IV. INTRODUCED SINCE THE ADVENT OF EUROPEANS

*Trees, Shrubs, Herbaceous Perennials*

*Bambusa vulgaris* Schrad. & Wendl. .C
*Lantana Camara* L.....C
*Psidium Cattleyanum* Sabine.....F
" *Guayava* L.....C
*Passiflora edulis* Sims.....VF
" *laurifolia* L.....VF

*Herbs*

*Bidens pilosa* L.....R
*Crepis Japonica* Benth.....C
*Physalis Peruviana* L.....C
*Senecio vulgaris* L.....F
*Sonchus oleraceus* L.....F

## 16. ALGAE OF THE STREAMS AND WATERFALLS OF THE LOWER AND MIDDLE FOREST ZONES

*Anabaena catenula* Bornet.
*Aphanothece Naegeli* Wartmann.
*Cladophora fracta* Ag.
" *nitida* Kuetz.
*Coleochaete irregularis* Pringsh.
" *orbicularis* Pringsh.
*Conferva bombycina* var. *minor* Wille.
*Cylindrospermum catenatum* Ralfs.
" *stagnale* Bornet.
*Draparnaldia macrocladia* Nordst.
*Fischerella ambigua* Gomont.
*Gloeocapsa magma* Kuetz.
" *polydermatica* Kuetz.
" *quarternata* Kuetz.

*Lyngbya cladophorae* Tilden.
" *Martensiana* Menegh.
*Mougetia capucina* Ag.
*Nostoc foliaceum* Mougeot.
" *verrucosum* Vaucher.
*Oedogonium crispum* var. *Haviense* Nordst.
Oedogonium spp.
*Oscillarotia sancta* Kuetz.
" *formosa* Bory.
*Phormidium favosum* Gomont.
*Phormidium papyraceum* Gomont.
*Schroederia setigera* Lemm.
*Scytonema guyanense* Bornet.
" *ocellatum* Lyngb.
" *rivulare* Borzi.
" *varium* Kuetz.
Spirogyra spp.
*Spirulina major* Kuetz.
*Stigeoclonium tenue* Kuetz.
*Tolypothrix distorta* Kuetz.
*Ulothrix minulata* Kuetz.

## 17. RAVINES

Between the grassy ridges specified as "zone two" of the valley head are deep, narrow, steep-walled ravines, lying between the 700- and 1,400-ft. contours. These ravines are not to be confused with the hanging valleys, which occupy a higher level—1,400 to 2,000 feet—and are mantled with the true rain-forest vegetation. The ravines are occupied by plants of the *lower forest zone*. These narrow, humid gorges are the regions of minimum illumination in the valley. Their floors receive no direct sunlight until an advanced hour of the morning. The eastern arc of the sky is shut out by the mountain wall. These ravines are so narrow—their streamways are but 8 to 15 feet wide—that sunlight can enter only directly from above, and from the front, *i. e.*, facing the main valley. The subdued illumination is augmented by the cloud-cap that lies across the summit ridge. The gloominess contrasts strikingly with the glare of the main valley floor.

The larger arborescent species that are most prevalent in the ravines are: *Aleurites moluccana*, *Eugenia Malaccensis*, *Charpentiera ovata*, *Pipturus albidus*, *Urera Sandwicensis*, *Elaeocarpus bifidus*, *Clermontia macrocarpa*.

Under the shade of these trees occur a number of smaller species that are characteristically shade tolerant, for example: *Lysimachia Hillebrandii*, *Rollandia grandifolia*, *R. lanceolata*, *Cordyline terminalis*, *Smilax Sandwicensis*, *Oplismenus compositus*, *Zingiber Zerumbet*, *Alocasia*, *Colocasia*, *Dioscorea* spp., *Curcuma*, *Musa*, *Touchardia latifolia*, *Crepis japonica*, and many pteridophytes.

The plants that grow in these cool, humid, shady, protected ravines are sharply contrasted, from the ecological standpoint, with those that inhabit the hot, arid, glaring, windswept foothill slopes. These two habitats represent two environmental extremes.

## 18. THE ZONE OF KOA AND LEHUA

Directly above the kukui zone and commingling with it along its upper limits is the zone dominated by the *koa*, *Acacia Koa*, and the *lehua*, *Metrosideros polymorpha*. Originally the *koa* was much more abundant than it is at present; at this time practically all of the large koa has been cut or killed and the trees which remain are only of medium stature. The *lehua* is the most abundant tree in the Manoa forests, and in the forests of the archipelago as a whole. Both it and the *koa* attain their optimum development on the island of Hawaii, particularly in the region of Puna and Olaa. In these districts trees of 75–90 feet are not uncommon; in Manoa the average height is 35 feet.

The zone of *koa* and *lehua* does not have as sharp horizontal boundaries as do some of the other plant zones. The *koa* thrives in Manoa at elevations as low as 50 feet and was at one time fairly plentiful in the valley floor, in districts from which it has been absent for the last fifty years. The upper limit of the *koa* is also somewhat indefinite, averaging 1,200 feet, but sometimes rising to nearly 1,800 feet. On the island of Hawaii the finest stands of *koa* occur at elevations of 4,000 to 5,000 feet. The *lehua* occurs scattered throughout the Manoa rain-forest, particularly along the ridges, and ascends the highest peaks. On the island of Hawaii it rises to a height of 9,000 feet.

## 19. DISTINCTIVE FEATURES OF THE MANOA RAIN-FOREST

1. The forest flora is composed almost wholly of arborescent, shrubby, or woody species. Most of them are endemic and many are confined to the island of Oahu. There are no gymnosperms.

2. The average stature of the trees is about 25 feet; many do not exceed 20 feet. The more stunted forms occur on the steep slopes and ridge crests; along the floors of the ravines the trees may rise to heights of 30 to 40 feet.

3. Most of the shrubs are tall and semi-arborescent in character; it is difficult to discriminate between the two habits.

4. The substratum is a thin layer of stiff, red soil, derived from the basaltic lavas which directly underlie it. This soil is continuously wet, and is exceedingly tenacious of its water. It contains very little organic matter, owing to the steepness of the slope and the rapidity of the erosion.

5. The forest forms an almost unbroken mantle, covering the peaks, slopes and ravines. The only gaps are those upon the very steep cliffs, and the rents caused by landslides. The landslides vary in width from 10–40 feet and in length from 20–400 feet. At any given time there are approximately 125 landslide scars visible in the Manoa rain-forest.

6. The foliage of the rain-forest vegetation is, in general, small, simple, oval, thick, coriaceous, and with a glossy upper surface. The prevailing color is a dark, dull, heavy green, approaching olive.

7. The vegetation is very slow-growing, and relatively small shrubs and trees show that they have attained considerable age (30 to 50 years).

8. The undergrowth is scanty, and consists mainly of bryophytes and the lesser species of pteridophytes. There is practically no grass or annual vegetation.

9. The flowers of the rain-forest are small and inconspicuous. There is no well-defined flowering season, and very few showy species.

10. Tree-ferns and palms comprise a very minor element in the rain-forest. Orchids are rare. Lianas are of a relatively few species, and are not as abundant as in the lower forest zone. Plants along the summit ridges, exposed to the wind, tend to assume krumholz forms.

11. Despite the heavy precipitation, the streams of the hanging valleys and ravines of the rain-forest are exceedingly inconstant in character, filling with great rapidity after a storm, and soon running almost dry.

12. In the absence of definite records for the Manoa rain-forest, the data given by Shreve[2] for the Jamaican rain-forest may be presented as suggestive and probably very nearly the same as for Manoa:

| | Temperature of the Soil | Of the Air |
|---|---|---|
| Annual mean | 61.6° F. | 60.8° F. |
| Annual mean range | 2.9° | 5.3° |

The humidity of the Jamaican forest (annual summary of monthly means for 15 years), is 84.1 percent; Manoa conditions are closely comparable to this.

## 20. HANGING VALLEYS

Above the abrupt slopes and precipices that frame the valley head is a series of little hanging valleys. They are separated from

[2] Loc. cit.

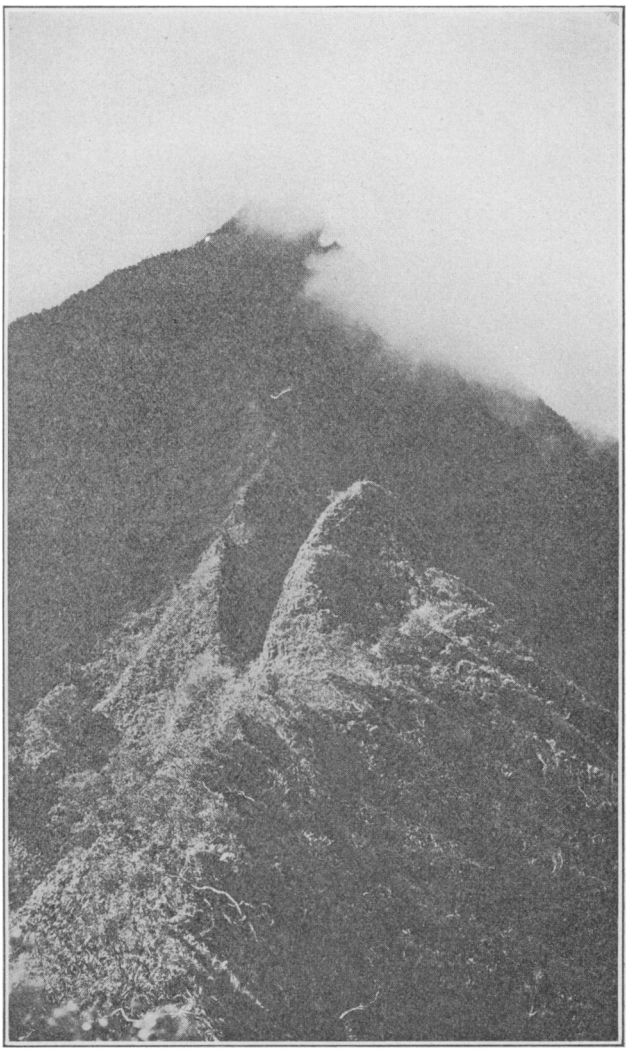

FIG. 12. Typical Koólan summit ridge and peak. Elevation of camera, about 2200 ft. Note precipices and forest mantle.

one another by steep-walled, knife-edged ridges. The ravines open upon the precipices, with vertical walls of 200 to 300 feet directly below their mouths, so they are true hanging valleys. They lie chiefly between the 1,400–2,000-ft. contours, although some reach up the slopes of Kona-hua-nui to 3,000 feet. The hanging valleys, like the summit ridges and peaks, are mantled with the somber greenery of the rain-forest.

The sides of these ravines are steep, and very difficult to climb. They are 45°–65°; the steeper declivities are constantly marked by landslides. These wounds cut through the soil to the underlying rock and remain bare for a long time.

### 21. SUMMIT RIDGES AND PEAKS

That portion of the main summit ridge of the Koolau Mountains which lies directly above the head of Manoa Valley, *i. e.*, between Kona-hua-nui and Olympus, is 1.7 miles long, measured along the crest. The ridge, viewed from above, is strongly curved, with its concave side facing northeast (windward), into the Ohu-ohi amphitheater. The windward wall is a great precipice, about 1,000 feet sheer, covered for the most part with scrubby vegetation, but impassable. The summit ridge forms an arc of 90°. The eastern half of this arc definitely bounds Manoa; the western half is part of the Kona-hua-nui mass. Erosion is rapidly bevelling the summit ridge, which has a strongly serrate silhuette. In the process of time a gap will be formed through the mountains, similar to the gaps at the heads of Nuuanu and Kahili Valleys. The summit ridge and peaks are covered with the dense drapery of the rain-forest.

The climate of the Manoa rain-forest is similar to that of all tropical montane forests. The temperatures are very constant and low as compared with those of the lowlands. Frost is unknown, and in the absence of accurate records, 45°–50° may be taken as a minimum. The rain-forest is far enough removed from the warm lowlands to be little influenced by them. The Oahu altitudes are not sufficient for alpine influences to be felt; this contrasts with the great mountains of the island of Hawaii, which rise to nearly 14,000 feet.

### 22. MOUNT KONA-HUA-NUI

Mount Kona-hua-nui is the highest peak—3,105 feet—in the Koolau Range. It lies as a mighty rampart directly northeast of

the head of Manoa. Although not physiographically an integral part of the Manoa region, it is of such ecologic importance that it is considered herewith.

The airline distance from the valley-head precipices to the extreme summit of Kona-hua-nui is about one mile. The most northern branch of Manoa Stream originates at an elevation of about 2,600 feet, very near the mountain summit. There is no other point along the Manoa summit-ridge that rises above 2,400 feet, and the average is about 2,200 feet. Thus all of the Kona-hua-nui region above 2,400

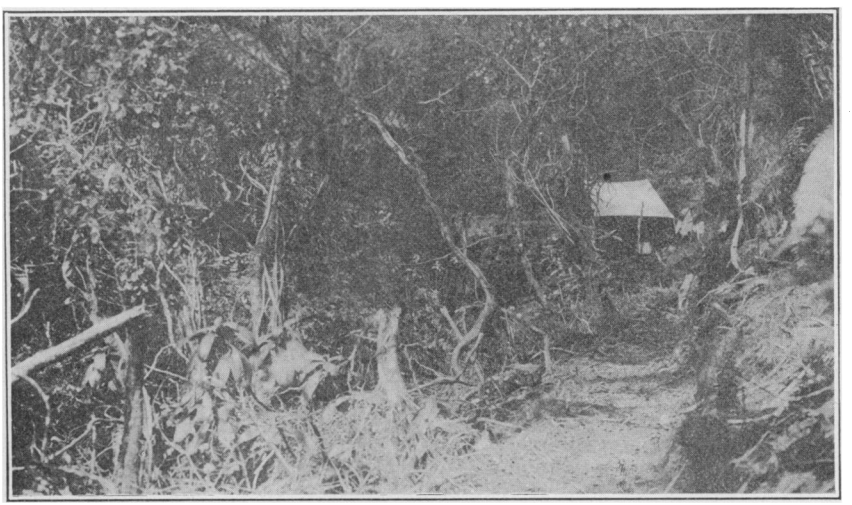

FIG. 13. Trail and camp in the Manoa rain forest. In the upper portion of a hanging valley on the side of Kona-hua-nui.

feet comprises a life area which is without counterpart in any other adjacent portion of the Manoa mountains. Certain plants are very distinctive of these upper levels, and are rarely or never met below the 2,400-ft. contour. Some of these are: *Hesperomannia arborescens*, *Cheirodendron platyphyllum*, *Exocarpus brachystachys*, *Vaccinium penduliflorum* var. *gemmaceum*, *Lobelia Gaudichaudii*, *Lobelia macrostachys*, etc.

Owing to its elevation Kona-hua-nui is a great rain-maker. The trade winds become chilled in rising over it, the copious moisture condenses, and a characteristic cloud-cap covers the mountain summit

during most of the year. Torrential precipitation occurs on both the windward and leeward slopes, and averages about 100 inches annually. This heavy rainfall has cut the east and west faces of the mountain into very steep precipices. The north and east faces are part of the famous Koolau *pali*. The south and west faces are fretted with hanging valleys, which debouch into Nuuanu and Manoa Valleys.

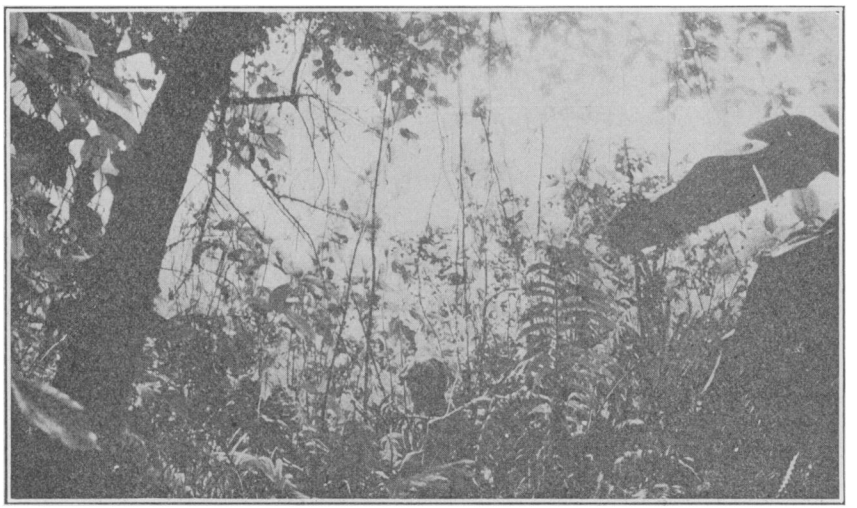

FIG. 14. View in the rain forest, showing lianas. Note man's head in center foreground, indicating height of undergrowth.

## 23. MOUNT OLYMPUS

Mount Olympus (Awawaloa) forms on the summit ridge the eastern boundary of the Manoa region. It rises to an elevation of 2,447 feet and closely resembles Kona-hua-nui in physiography and vegetation. It is covered with the typical rain-forest vegetation; the peak itself is wind-swept and the vegetation, like that of all the summit peaks and ridges, gives every evidence of very unfavorable life-conditions.

## 24. REPRESENTATIVE PLANTS OF THE MANOA RAIN-FOREST

GROUP I. ENDEMIC

Ia. *Trees*

*Acacia Koa* Gray.....F
*Antidesma platyphyllum* Mann.....F
*Bobea elatior* Gaud.....F
*Broussaissia arguta* Gaud.....C
*Charpentiera ovata* Gaud.....C
*Cheirodendron Gaudichaudii* Seem....C
" *platyphyllum* Seem....R
*Claoxylon Sandwicense* Mueller.....F

*Dubautia plantaginea* Gaud. . . . . C
*Elaeocarpus bifidus* Hook. & Arn. . . . C
*Eugenia Sandwicensis* Gray . . . . . R
*Eurya Sandwicensis* Gray . . . . . R
*Exocarpus brachystachys* Hillebr. . . . . R
*Hesperomannia arborescens* Gray . . . . R
*Ilex Sandwicensis* Loes. . . . . C
*Labordia membranacea* Mann . . . . . C
" *sessilis* Gray . . . . . C
" *tinifolia* Gray . . . . . F
*Maba Sandwicensis* DC. . . . . C
*Metrosideros macropus* Hook. & Arn. . R
" *polymorpha* Gaud. . . . . C
" *rugosa* Gray . . . . . C
" *tremuloides* Rock . . . . . F
*Ochrosia Sandwicensis* Gray . . . . . R
*Osmanthus Sandwicensis* Knobl. . . . . F
*Pelea clusiaefolia* Gray . . . . . F
" *Sandwicensis* Gray . . . . . C
" *rotundifolia* Gray . . . . . F
*Perrottetia Sandwicensis* Gray . . . . . C
*Pittosporum glabrum* Hook. & Arn. . . F
" *glomeratum* var. *acutisepalum* Hillebr. . F
" *spathulatum* Mann . . . . . F
*Platydesma campanulata* Mann . . . . . F
" *cornuta* Hbd. . . . . R
*Pritchardia Martii* Wendl. . . . . F
*Psychotria hexandra* Mann . . . . . C
*Pteralyxia macrocarpa* Schult. . . . . R
*Pterotropia gymnocarpa* Hillebr. . . . . R
*Santalum Freycinetianum* Gaud. . . . . F
*Sapindus Oahuensis* Hillebr. . . . . R
*Sideroxylon Sandwicense* Benth. & Hook. . . . . F
*Straussia Fauriei* Levl. . . . . R
" *kaduana* Gray and vars. . . . C
" *longissima* Rock. . . . . C
" *Mariniana* Gray . . . . . F
*Suttonia Lessertiana* Mez. . . . . C
*Tetraplasandra meindra* Harms . . . . . C
" *Oahuensis* Harms. . . . F
*Xanthoxylum Oahuensis* Hillebr. . . . . F
" *dipetalum* Mann . . . . . R

### Ib. *Shrubs*

Sometimes more or less arborescent

*Artemisia australis* Less. . . . . R
*Campylotheca Sandwicensis* Hillebr. . . F
" (*Coreopsis*) *macrocarpa* Gray, and vars. . . . . C
*Clermontia macrocarpa* Gaud. . . . . C
" *oblongifolia* Gaud. . . . . F
*Coprosma foliosa* Gray . . . . . C
" *longifolia* Gray. . . . . F
*Cyanea angustifolia* Hillebr. and vars. . . . . C
" *acuminata* Hillebr. . . . . F
" *Grimesiana* Gaud. . . . . C
*Cyrtandra cordifolia* Gray . . . . . C
" *gracilis* Hillebr. and vars. . R
" *grandiflora* Gaud. . . . . F
" *Hillebrandi* Oliver . . . . . F
" *Kalihii* Wawra . . . . . F
" *latebrosa* Hillebr. . . . . F
" *Lessoniana* Gray. . . . . C
" *Macraei* Gray . . . . . R
" *paludosa* Gaud. and vars. . C
" *Pickeringii* Gray. . . . . C
" *triflora* Gaud. and vars. . . . F
*Delissea subcordata* Gaud. . . . . C
*Dubautia laxa* Hook. & Arn. . . . . F
*Euphorbia clusiaefolia* Hook. & Arn. . C
" *Hookeri* Steud. . . . . F
" *multiformis* Hook. & Arn. . C
*Gouldia coriacea* Gray . . . . . C
*Hibiscus Arnottianus* Gray . . . . . C
" *Kokio* Hillebr. . . . . R
*Joinvillea adscendens* Gaud. . . . . R
*Kadua cordata* Cham. & Schlecht. . . . F
" *acuminata* Cham. & Schlecht. . C
*Labordia lophocarpa* Hillebr. and vars. . . . . F
*Lipochaeta connata* DC. var. *decurrens* Hillebr. . . . . C
*Lobelia Gaudichaudii* DC. . . . . C
" *macrostachys* Hook. & Arn. . . F
*Nothocestrum longifolium* Gray. . . . . C
*Pelea Lydgatei* Hillebr. . . . . R
" *oblongifolia* Gray . . . . . R
*Phyllostegia glabra* Benth. . . . . C
" *grandiflora* Benth. . . . . C
" *hirsuta* Benth. . . . . C
" *parviflora* Benth. . . . . C
*Plantago princeps* Cham. & Schlecht. . R
*Rollandia calycina* G. Don . . . . . R

*Rollándia grandiflora* Hillebr .....F
" *Humboldtiana* Gaud.....F
" *lanceolata* Gaud. and vars..F
" *longiflora* Wawra var. *angustifolia* Hillebr.....R
" *racemosa* Hillebr.....R
*Scaevola Chamissoniana* Gaud.....C
" *glabra* Hook. & Arn.....F
" *mollis* Hook. & Arn.....F
*Schiedea Nuttallii* Hook.....F
*Smilax Sandwicensis* Kunth.....VC
*Solanum Sandwicense* Hook. & Arn..F
Stenogyne spp.....F
*Suttonia Sandwicensis* Mez.....F
*Tetramolopium Chamissonis* Gray...R
*Urera Sandwicensis* Wedd.....F
*Vaccinium penduliflorum* Gaud.....C
*Viola Chamissoniana* Gingins.....F
*Viscum articulatum* Burm. and vars..C
*Wikstroemia Oahuensis* Rock.....F

Ic. *Herbaceous Perennials and Herbs*

*Astelia veratroides* Gaud.....F
*Alyxia olivaeformis* Gaud.....C
*Baumea Meyenii* Kunth.....F
*Carex Oahuensis* Meyer.....F
*Gahnia Beecheyi* Mann.....F
*Gunnera petaloidea* Gaud.....R
*Isachne distichophylla* Munro.....R
" *pallens* Hillebr.....R
*Liparis Hawaiiensis* Mann.....R
*Peperomia blanda* Kunth.
" *Eekana* C. DC.
" *hypoleuca* Miq.
" *insularum* Miq.
" *Koolauana* C. DC.
" *latifolia* Miq.
" *membranacea* Hook. & Arn.
" *pachyphylla* Miq.
" *parvula* Hillebr.
" *reflexa* Dietr.
" *Sandwicensis* Miq.
*Rhynchospora thrysoidea* Nees & Meyen.....F
*Trisetum glomeratum* Trin.....C

Id. *Pteridophytes*

*Asplenium acuminatum* Hook. & Arn.....R
" *contiguum* Kaulf.....F
" *glabratum* Robins.....R
" *Hillebrandii* C. Chr.....R
" *Kaulfussii* Schlecht.....R
" *lobulatum* Mett.....R
" *nitidulum* Hillebr.....R
" *patens* Kaulf.....R
" *pavonicum* Brack.....R
" *pseudo-falcatum* Hillebr...C
" *schizophyllum* C. Chr.....F
" *vexans* Heller.....R
*Athyrium deparioides* C. Chr.....R
" *proliferum* C. Chr.....F
*Botrychium subbifoliatum* Brack.....R
*Cibotium Chamissoi* Kaulf.....C
" *Menziesii* Hook.....F
" *glaucum* Hook. & Arn.....R
*Cyrtomium Boydiae* Robins.....R
*Dicranopteris emarginata* Robins.....F
*Diellia pumila* Brack.....R
" *falcata* Brack.....R
*Diplazium arboreum* Robins.....R
" *Fenzlianum* C. Chr.....R
*Doodia Kunthiana* Gaud.....C
*Doryopteris decora* Brack.....R
*Dryopteris acutidens* C. Chr.....R
" *crinalis* C. Chr.....F
" *Hawaiiensis* Robins.....R
" *Honolulensis* C. Chr.....F
" *Keraudreniana* C. Chr....F
" *latifrons* Kuntze.....F
" *nuda* Underw.....F
" *rubiginosa* Kuntze.....F
" *squamigera* Kuntze.....F
" *unidentata* C. Chr.....F
*Elaphoglossum micradenium* Moore..C
" *reticulatum* Gaud.....C
*Filix Douglassii* Robins.....R
*Hymenophyllum Baldwinii* Eaton....R
" *recurvum* Gaud....C
" *lanceolatum* Gaud..R
*Lycopodium nutans* Brack.....R
" *venustulum* Gaud.. ....R

*Lycopodium polytrichoides* Kaulf.....F
*Marattia Douglassii* Baker.....F
*Odontoloma macraeanum* Brack.....C
*Polypodium abietinum* Eaton.....R
" *adenophorus* Hook. & Arn.....F
" *Haaliliolanum* Brack....R
" *hymenophylloides* Kaulf..R
" *pellucidum* Kaulf.....C
" *pseudogrammitis* Gaud. .C
" *pumilum* Robins.....F
" *Saffordii* Maxon.....C
" *sarmentosum* Brack.....C
" *tamariscinum* Kaulf.....C
" *tripinnatifidum* Presl....R
*Pteris irregularis* Kaulf.....F
*Sadleria Souleytiana* Moore.....F
*Schizaea robusta* Baker.....R
*Schizostege Lydgatei* Hillebr.....R
*Selaginella arbuscula* Spring.....F
" *Springii* Gaud.....F
*Trichomanes cyrtotheca* Hillebr.....R

GROUP II. INDIGENOUS

IIa. *Trees*

*Dodonaea viscosa* L.....C
*Metrosideros polymorpha* Gaud.....C
*Pisonia umbellifera* Blume.....C
*Trema Amboiensis* Blume.....R

IIb. *Shrubs and Herbaceous Perennials*

*Dianella odorata* Blume.....C
*Lythrum maritimum* H. B. K. .....F
*Strongylodon lucidum* Seem.....VF

IIc. *Herbs*

*Daucus pusillus* Michx.....F
*Nertera depressa* Banks.....F

IId. *Pteridophytes*

*Adiantum capillus-veneris* L.....C
*Asplenium horridum* Kaulf.....C
" *insiticium* Brack.....F
" *monanthes* L.....R
" *unilaterale* Lam.....C
*Coniogramme fraxinea* Diels.....F
*Cyrtomium caryotideum* Presl.....F
*Dicranopteris glauca* Under.....F
" *linearis* Underw.....C
*Diplazium Sandwichianum* Diels.....F
*Dryopteris truncata* Kuntze.....F
*Elaphoglossum aemulum* Brack.....R
" *gorgonium* Brack.....F
" *hirtum* C. Chr.....C
*Hymenophyllum obtusum* Hook. & Arn.....R
*Hypolepis punctata* Mett.....R
*Lycopodium cernuum* L.....C
" *serratum* Thunb.....F
" *phyllanthum* Hook. & Arn.....C
*Ophioglossum pendulum* L.....C
*Polypodium Hookeri* Brack.....F
*Pteridium aquilinum* Kuhn.....F
*Pteris excelsa* Gaud.....C
*Psilotum complanatum* Sw.....F
" *nudum* Griseb.....C
*Trichomanes humile* Forst.....F
" *parvulum* Poir.....F
*Vittaria rigida* Kaulf.....C

GROUP III. INTRODUCED BY THE PRIMITIVE HAWAIIANS

*Touchardia latifolia* Gaud.....F
*Musa sapientum* L.....C

GROUP IV. INTRODUCED SINCE THE ADVENT OF EUROPEANS

*Buddleia Asiatica* Lour.....R
*Lantana Camara* L.....R
*Psidium Guayava*.....R

SUMMARY OF THE RAIN-FOREST VEGETATION

| | Species |
|---|---|
| Trees | 59 |
| Shrubs | 68 |
| Herbaceous perennials | 26 |
| Herbs | 6 |

| | | | |
|---|---|---|---|
| Endemic | 198 | Introduced since advent of Europeans | 3 |
| Indigenous | 37 | Pteridophytes | 93 |
| Introduced by primitive Hawaiians | 2 | | |

ENDEMIC VEGETATION OF THE RAIN-FOREST

| | Common | Frequent | Rare |
|---|---|---|---|
| Trees | 18 | 19 | 13 |
| Shrubs | 26 | 26 | 12 |
| Herbaceous-perennials and herbs | 2 | 5 | 4 |
| (11 spp. Peperomia, abundance uncertain) | | | |
| Pteridophytes | 12 | 21 | 32 |

## 25. BIRDS OF THE MANOA RAIN-FOREST

ALL ENDEMIC

*Group I. Species that Have Become Extinct within Historic Times*

Oahu Thrush, *Phaeornis Oahuensis* Wilson.
Oahu Akialoa, *Hemignathus Ellisianus* Gray.
Oahu Akiapolaau, *Heterorhynchus lucidus* Lichenst.
Oahu Akepeuie, *Loxops rufa* Bloxam; on verge of extinction.
Oahu Ou, *Psittirostra olivacea* Rothsch.
Oahu O-O, *Moho apicaulis* Gould.

*Group II. Species that are Present, in Small Numbers, at the Present Time*

Oahu Elepaio, *Chasiempis Gayi* Wilson.
Oahu Amakihi, *Chlorodrepanis chloris* Cabanis.
Oahu Creeper, *Oreomyza maculata* Cabanis.
Iiwi, *Vestaria coccinea* Forster.
Akakani, *Himatione sanguinea* Gmelin.

## 26. ORIGIN OF THE ENDEMIC FLORA

One of the most interesting problems connected with a study of the Manoa phytogeography is that of the origin of the large endemic flora, particularly that of the rain-forest. Shreve's excellent statement[3] is worthy of quotation at length:

"There is no type of vegetation in which may be found a wider diversity of life forms than exist side by side or one above the other in a tropical montane forest. Together with the structural diversities, discoverable in the field or at the microscope, are diversities of physiological behavior, discoverable by observation or experiment, and sometimes correlated with the structural features. There are quite as high degrees of specialization to be found in the rain-forest as may be sought in the desert. The prolonged occurrence of rain, fog, and

[3] Loc. cit., pp. 109–10.

high humidity at relatively low temperatures places the vegetation of a montane rain-forest under conditions which are so unfavorable as to be comparable with the conditions of many extremely arid regions. The collective physiological activities of the rain-forest are continuous but slow; those of arid regions are rapid, but confined to very brief periods. In the regions of the earth which present intermediate conditions between those of the desert and the reeking montane rain-forest may be sought the optimum conditions for the operation of all essential plant processes. It is indeed, in such intermediate regions—tropical lowlands and moist temperate regions—that the most luxuriant vegetation of the earth may be found, and it is also in such regions that the maximum origination of new plant structures and new species has taken place."

From the standpoint of conditions in the Hawaiian Islands, the closing words of the above quotation are of particular significance. Evidence is accumulating which indicates the former elevation of these islands *far above* their present levels. There undoubtedly has been a period of prolonged subsidence, amounting perhaps to several thousands of feet. The very rich endemic flora that today occupies the Manoa rain-forest very likely *did not originate there*, but rather upon warm lowlands that are now submersed beneath the ocean. In other words, Hawaii's remarkable endemic flora evolved upon prehistoric lowlands, and through slow subsidence of the land has been slowly crowded up the mountain slopes, into zones distinctly unfavorable for plant evolution. This hypothesis is also applicable to the various groups of animals—birds, snails, and insects, that today occupy the upper levels.

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